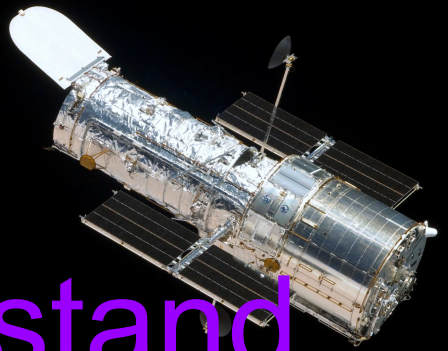
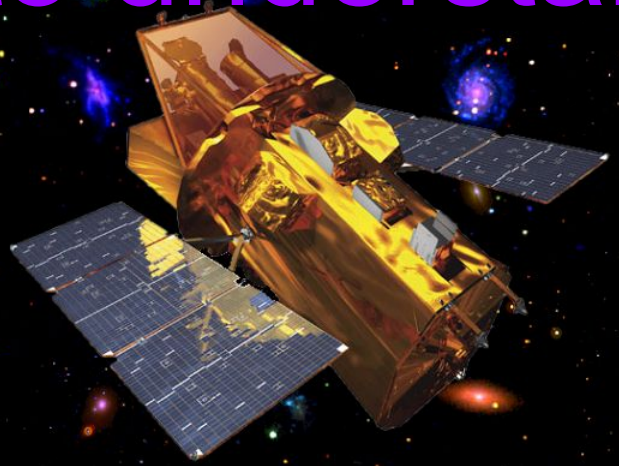
The Need for UV spectroscopy to understand photometry

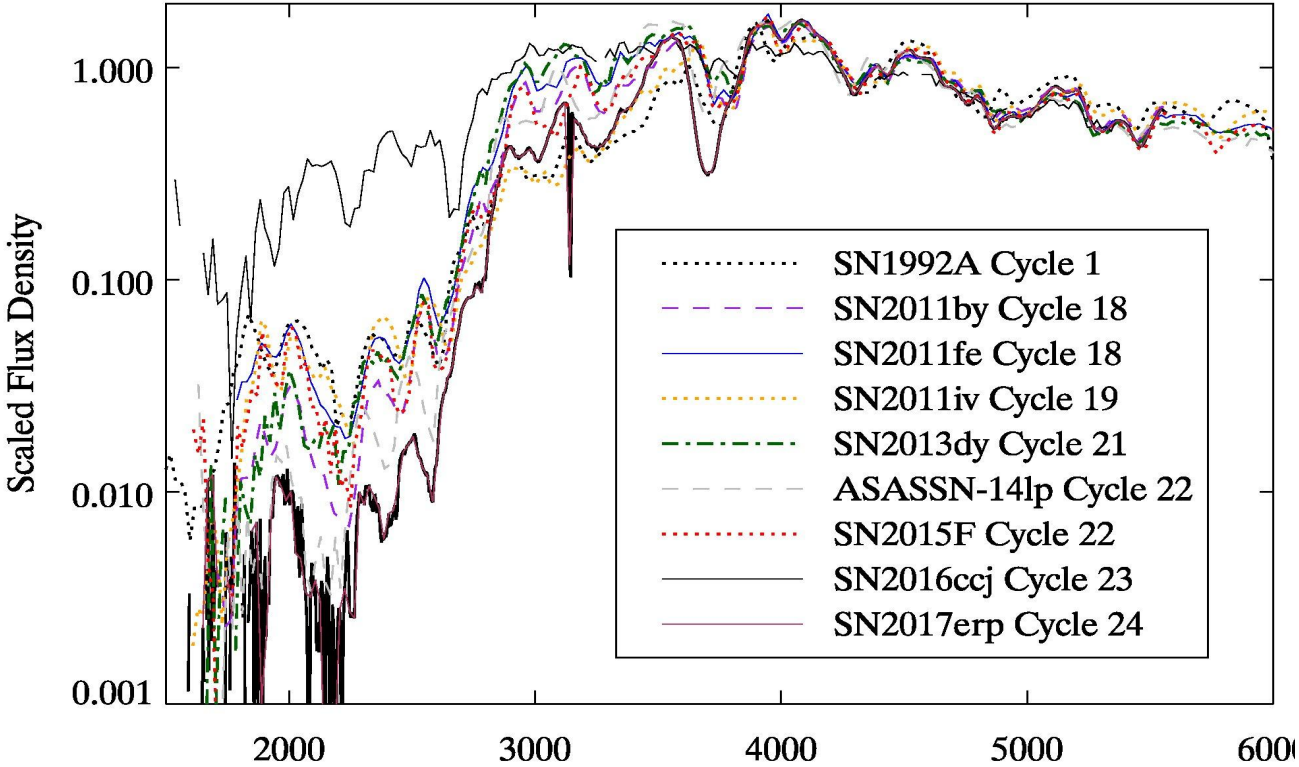




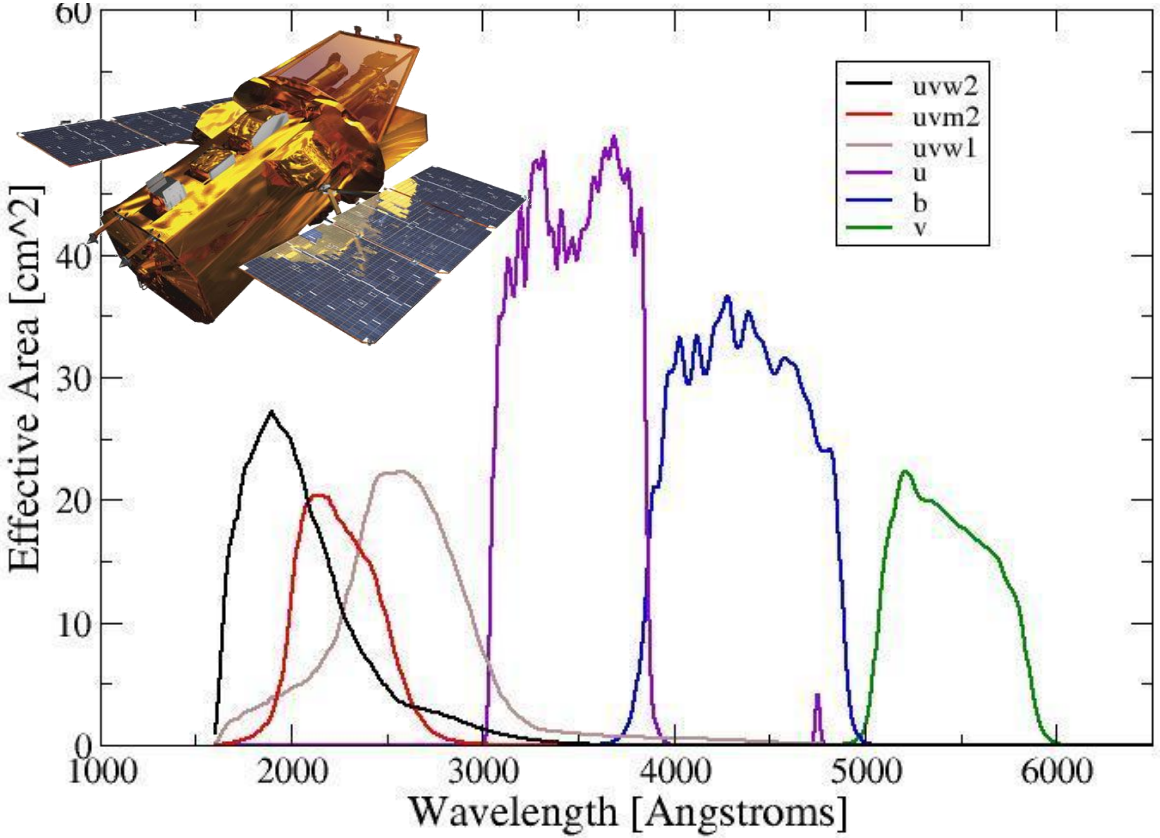
Dr. Peter J Brown
Mitchell Institute
Texas A&M University

I will talk about Swift UVOT filters and observations and the science of supernova analysis, but I want you to think about the more general process of how technical instrumental choices flow down to and affect the science to be done. This supernova talk is just a case study of how one can use or misuse data.

Type Ia Supernovae “Standard Candles” are very diverse in the UV



Swift UVOT filter Curves

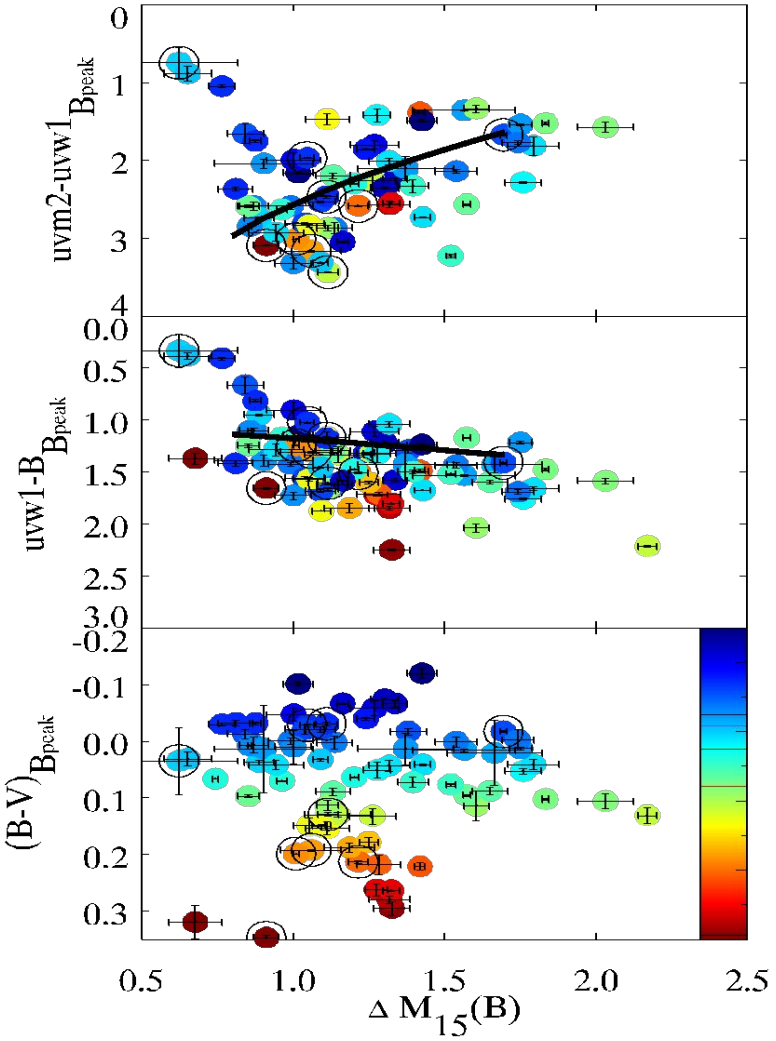


Ultraviolet Diversity of Type Ia Supernovae

Swift SN Ia colors at maximum light colored by B-V color.

Circled SNe have HST UV spectroscopy

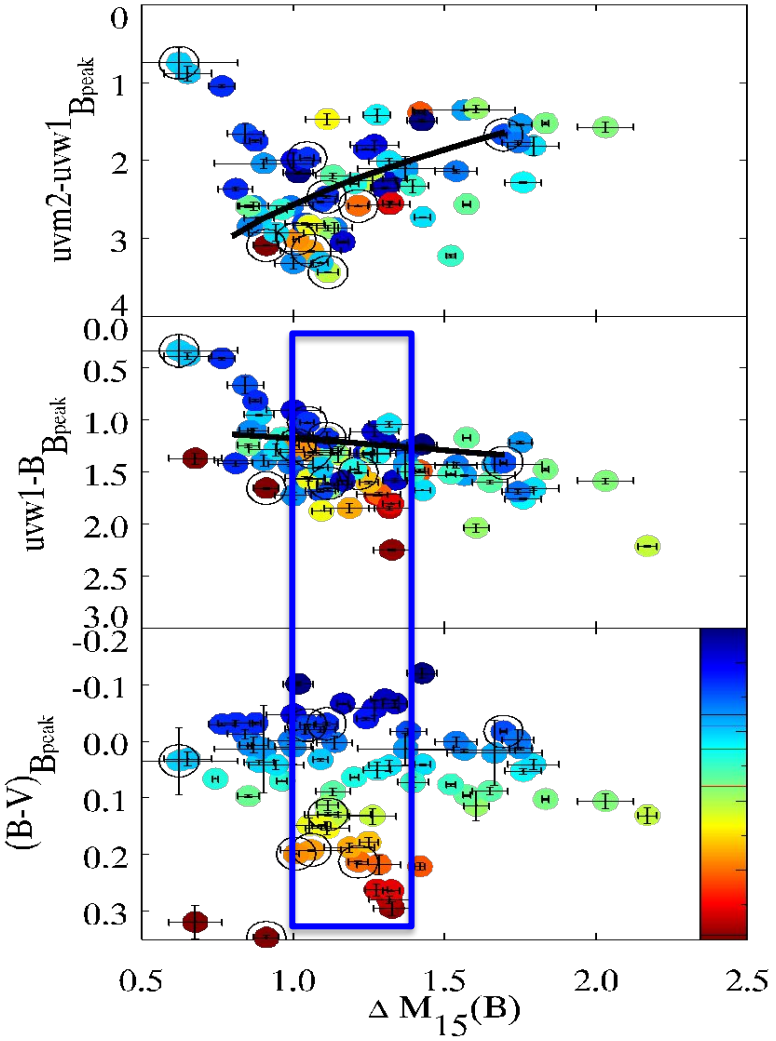
Black line is UV variation model from Foley et al. 2016

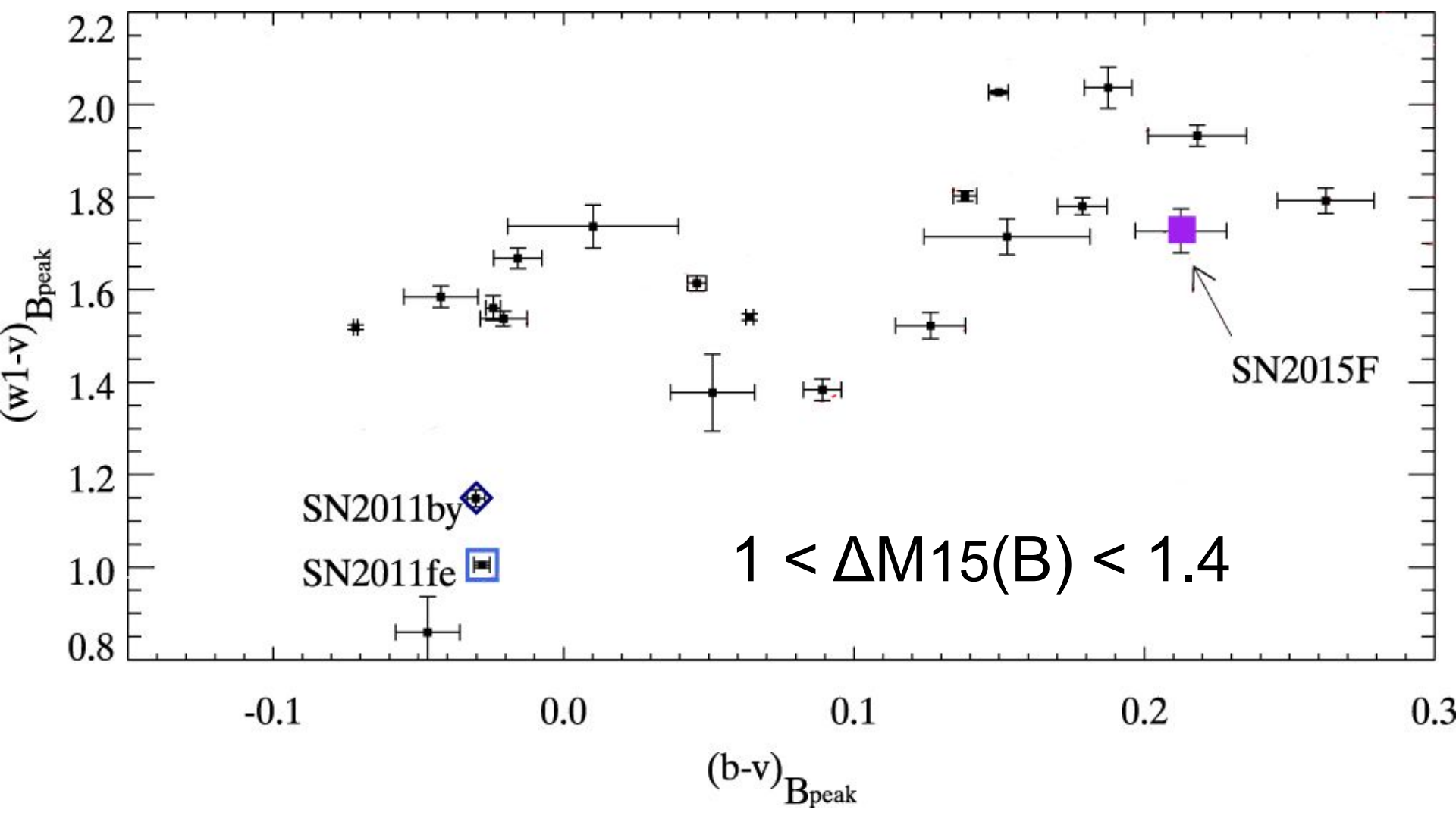


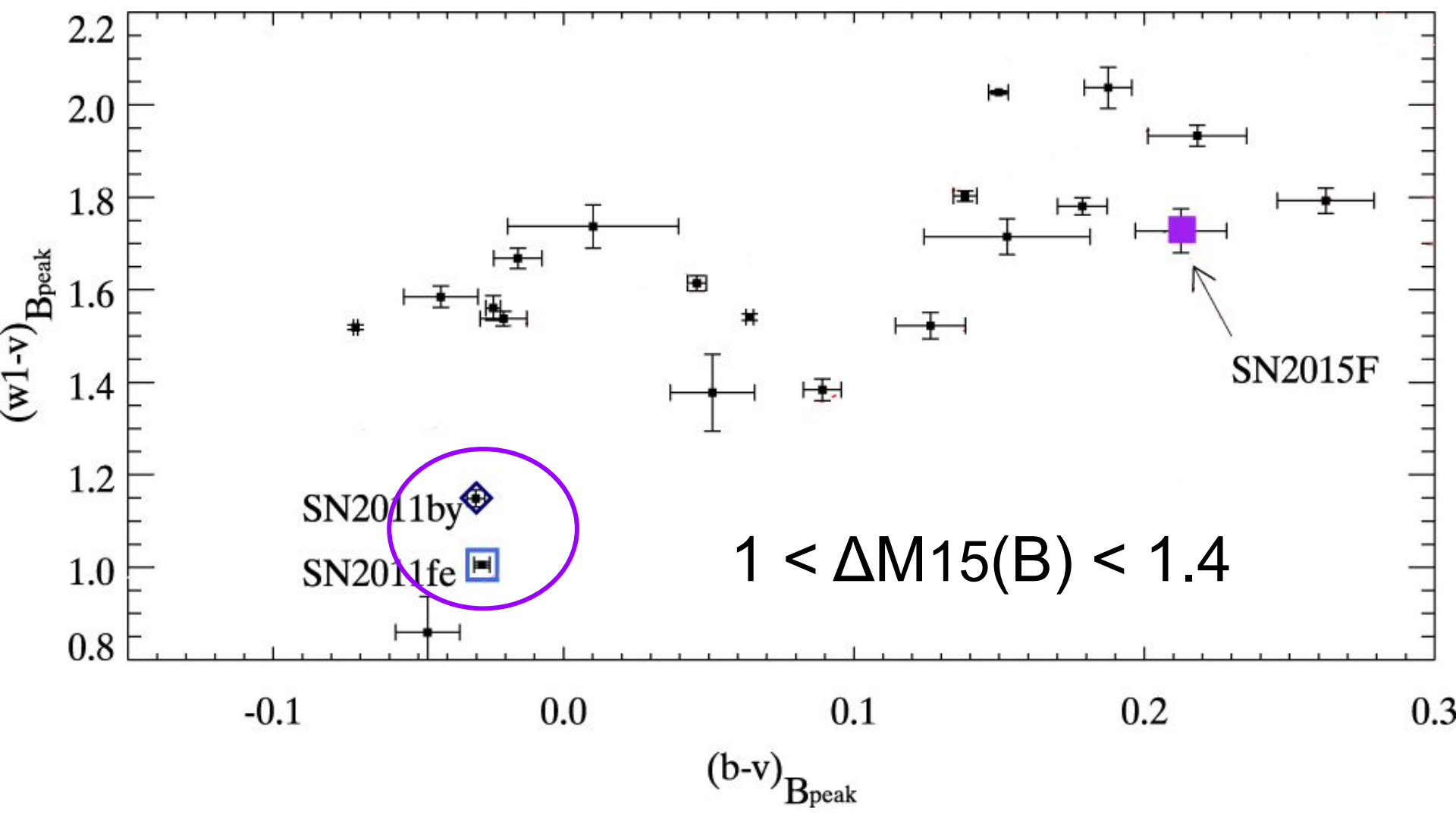
Ultraviolet Diversity of Type Ia Supernovae

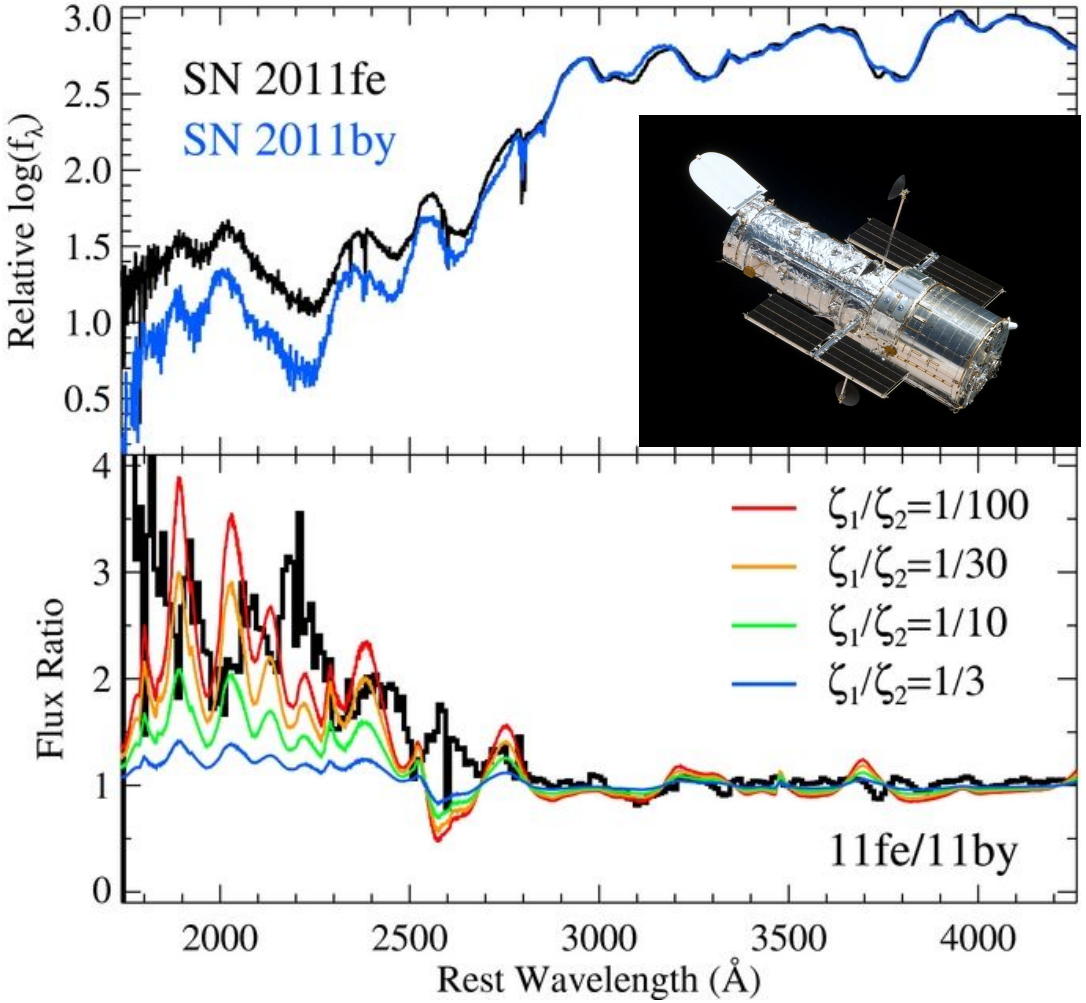
Swift SN Ia colors at maximum light colored by B-V color.

We will focus on the most normal of the standard candles used for cosmology.

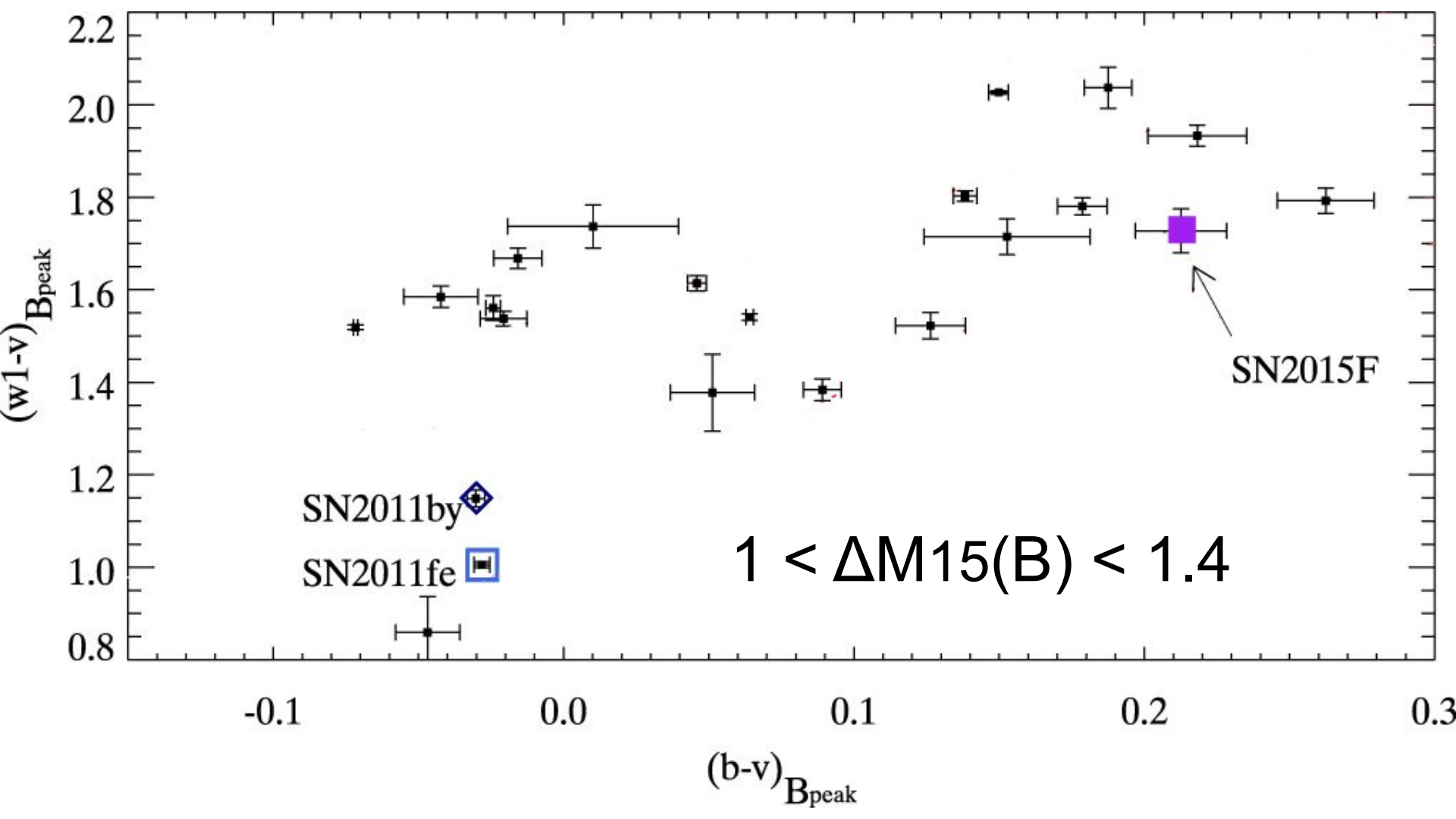


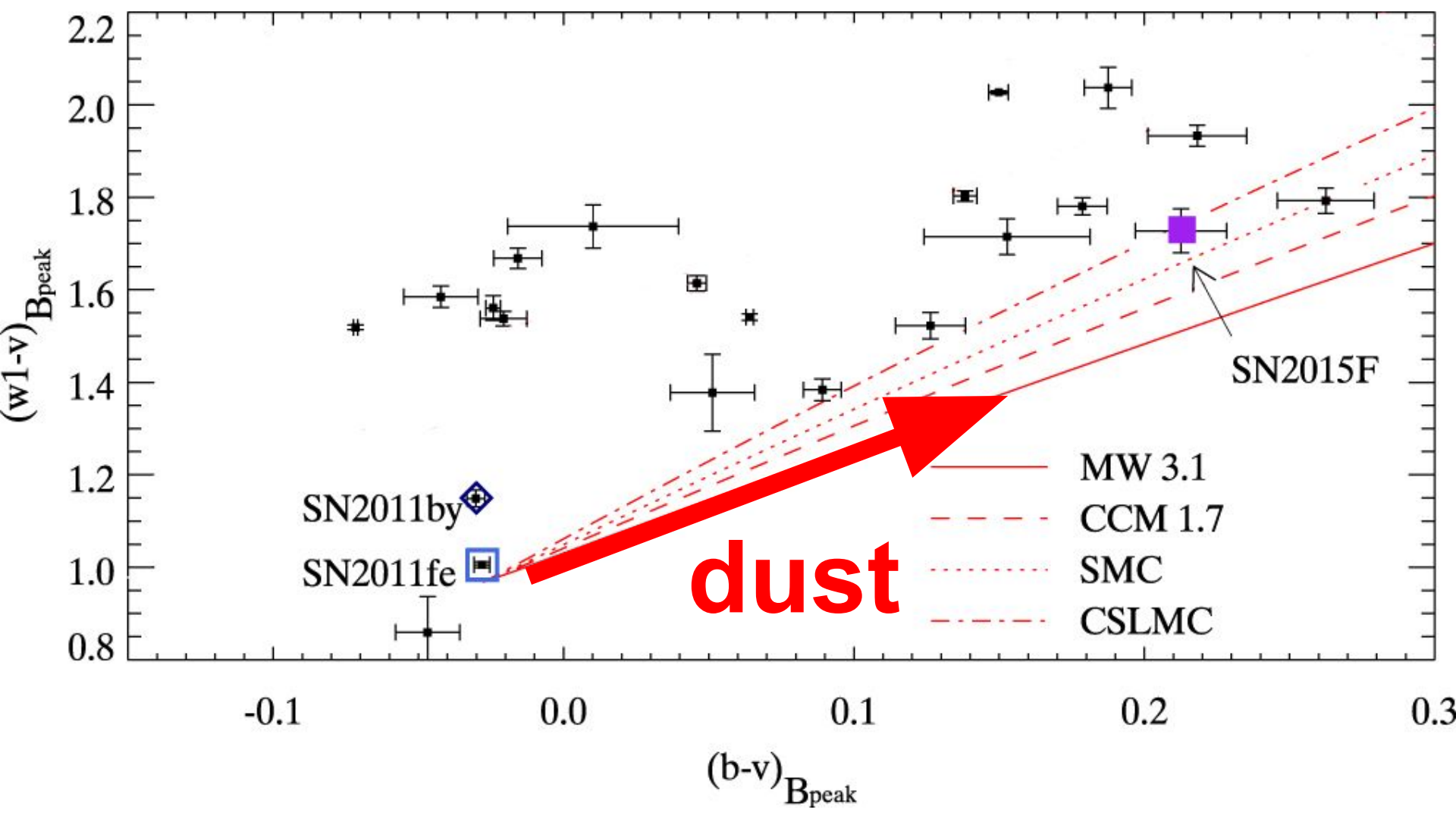

2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
(w1-v)Bpeak
-0.1
0.0
0.1
0.2
0.3
(b-v)Bpeak
SN2015F
SN2011by
SN2011fe
1 < ΔM15(B) < 1.4

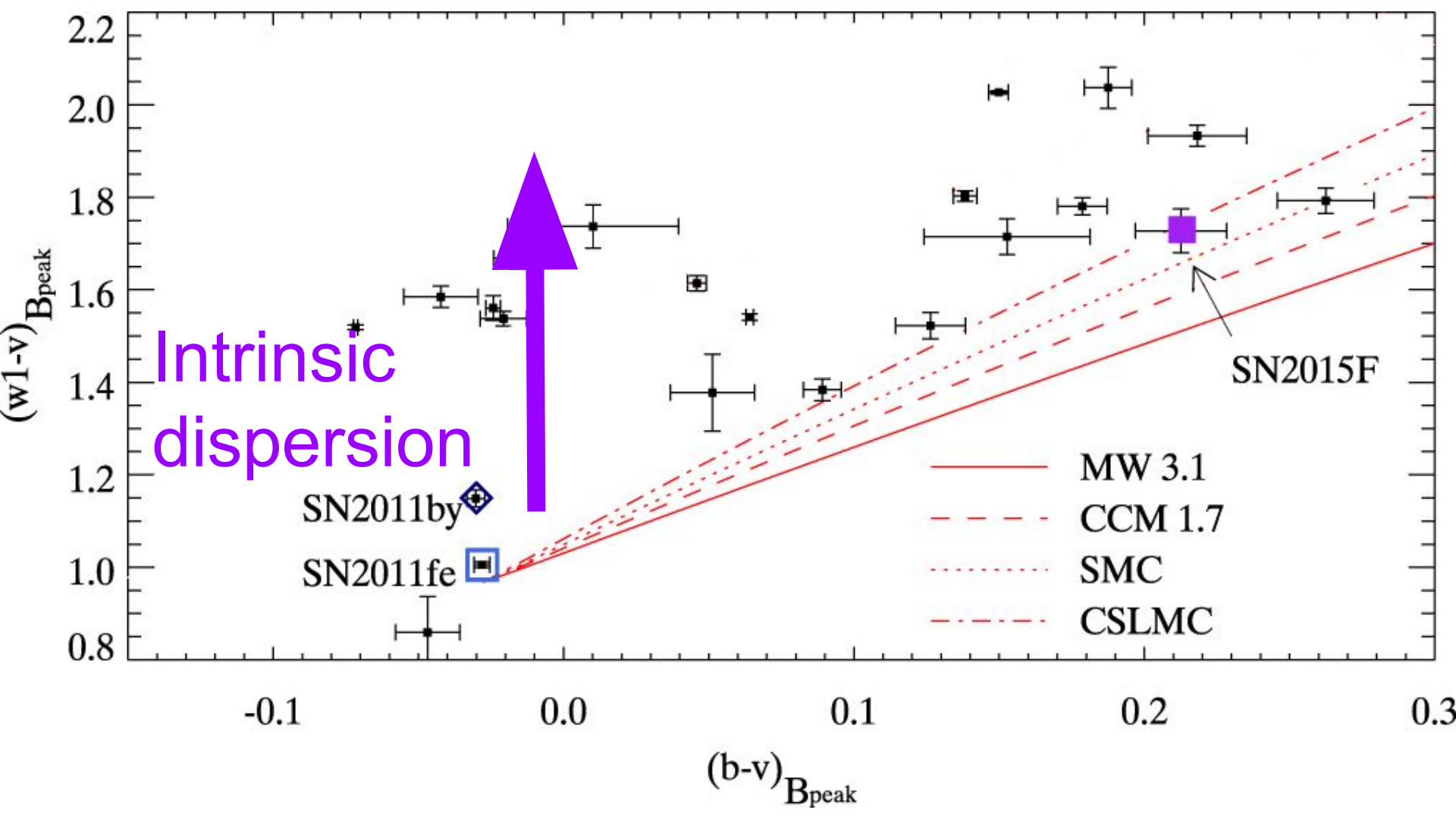

2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
(w1-v)Bpeak
-0.1
0.0
0.1
0.2
0.3
(b-v)Bpeak
SN2015F
SN2011by
SN2011fe
1 < ΔM15(B) < 1.4

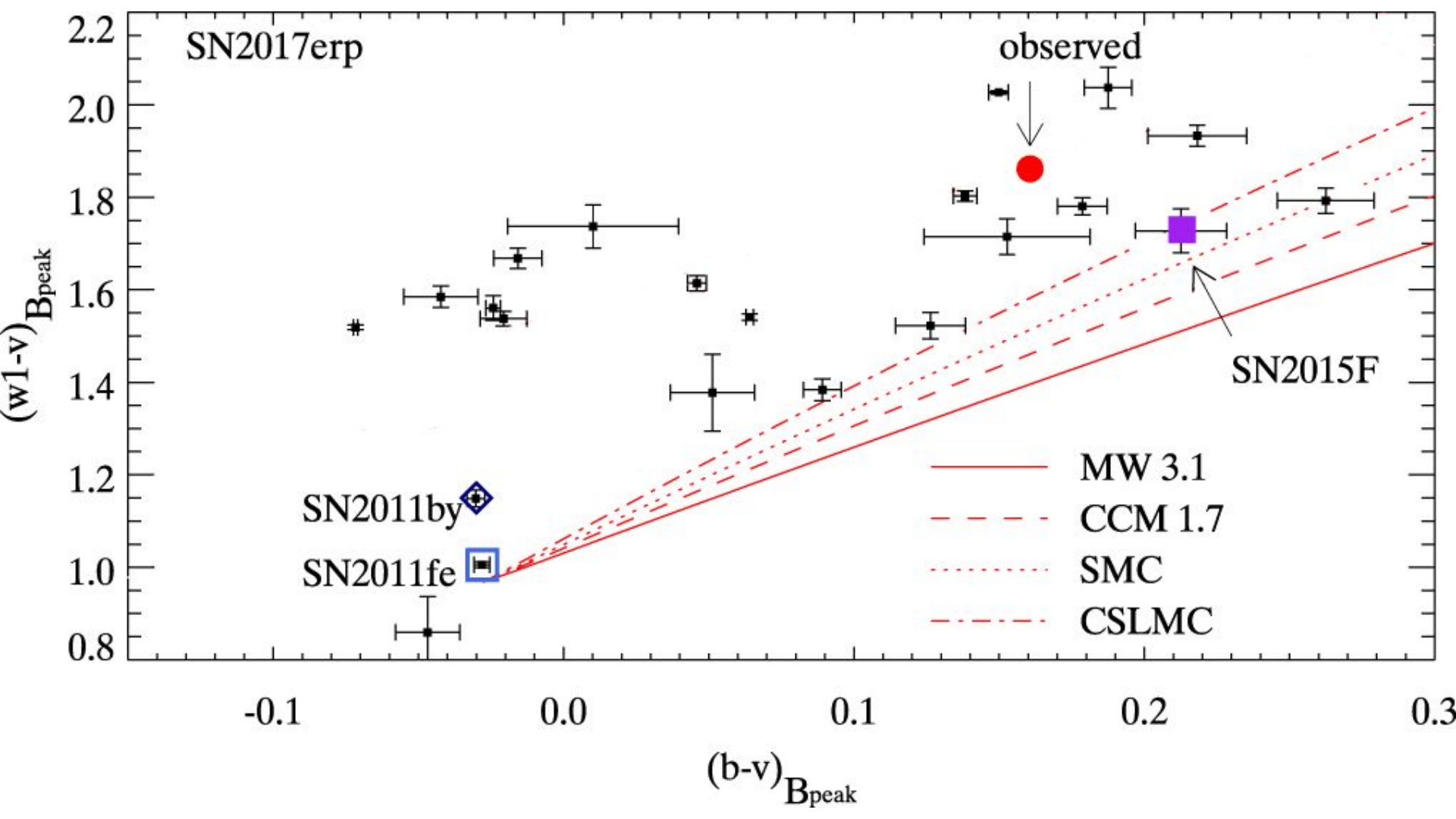


NUV “twins” SNe 2011fe and 2011by have different MUV continua (Foley & Kirshner 2013) attributed to metallicity difference based on Lentz et al. (2000) models

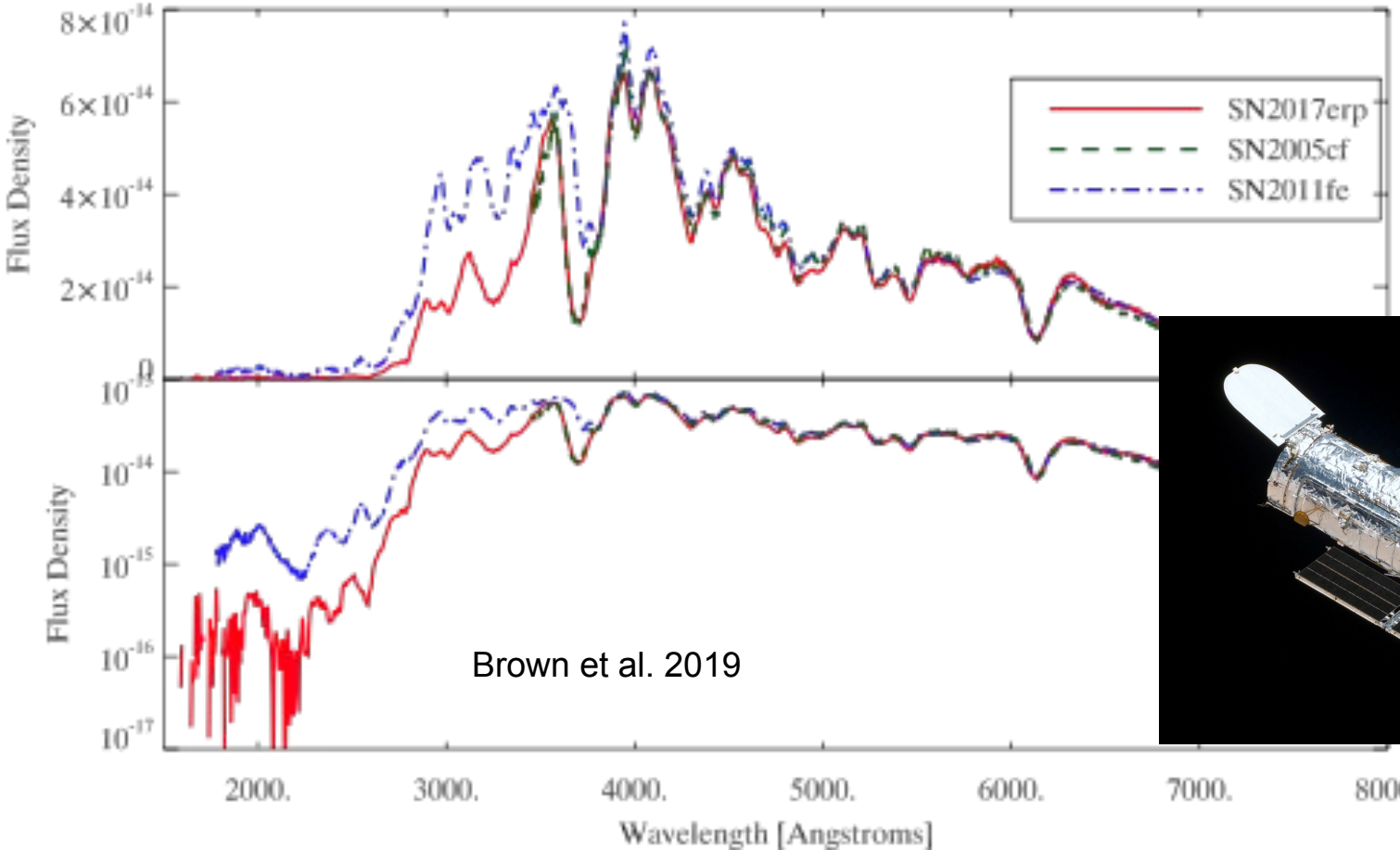

2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
(w1-v)Bpeak
-0.1
0.0
0.1
0.2
0.3
(b-v)Bpeak
SN2015F
SN2011by
SN2011fe
1 < ΔM15(B) < 1.4


2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
(w1-v)Bpeak
-0.1
0.0
0.1
0.2
0.3
(b-v)Bpeak
SN2011by
SN2011fe
SN2015F
dust
MW 3.1
CCM 1.7
SMC
CSLMC

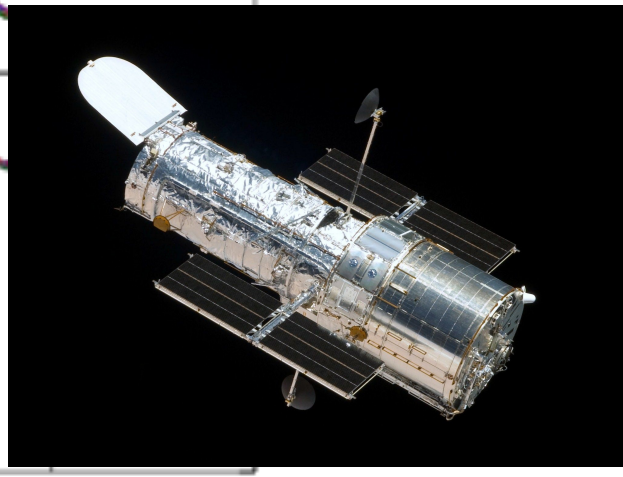

Intrinsic dispersion
SN2011by
SN2011fe
SN2015F
MW 3.1
CCM 1.7
SMC
CSLMC
$(w1-v)_{Bpeak}$
$(b-v)_{Bpeak}$
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
-0.1
0.0
0.1
0.2
0.3


SN2017erp
observed
SN2015F
SN2011by
SN2011fe
MW 3.1
CCM 1.7
SMC
CSLMC
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
-0.1
0.0
0.1
0.2
0.3
(w1-v)Bpeak
(b-v)Bpeak

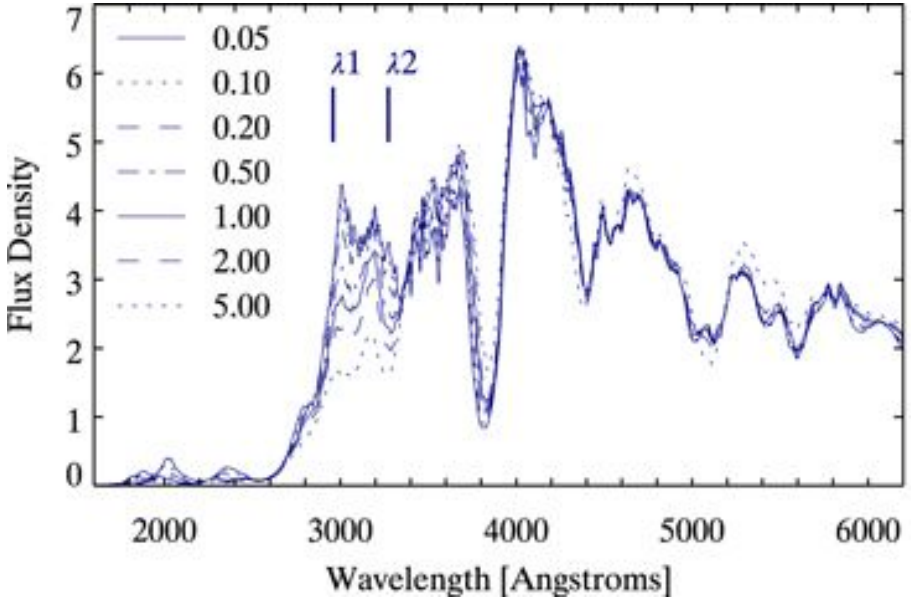
UV differences between SN2017erp and SN2011fe

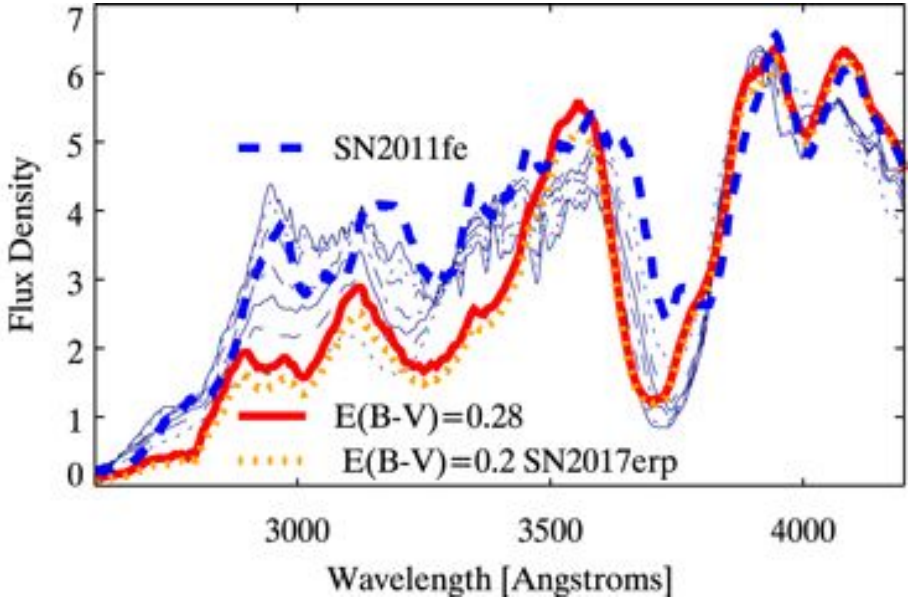


Brown et al. 2019

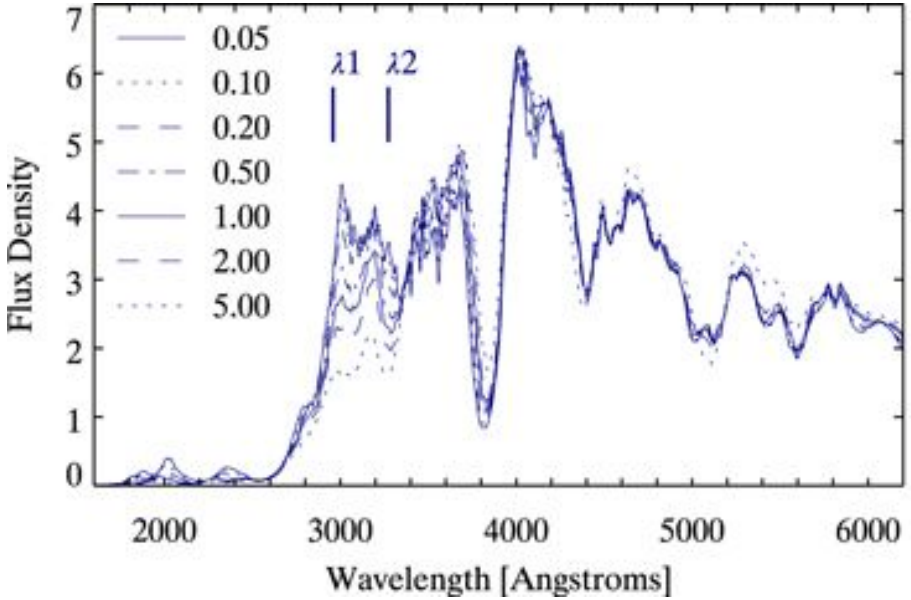


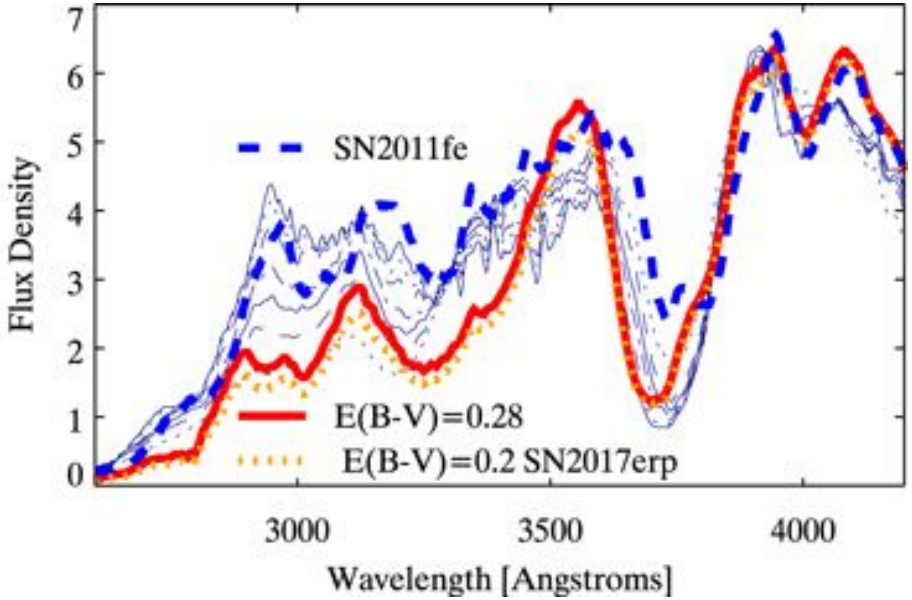
Comparisons with Walker et al. (2012) models point to metallicity as source of near-UV differences



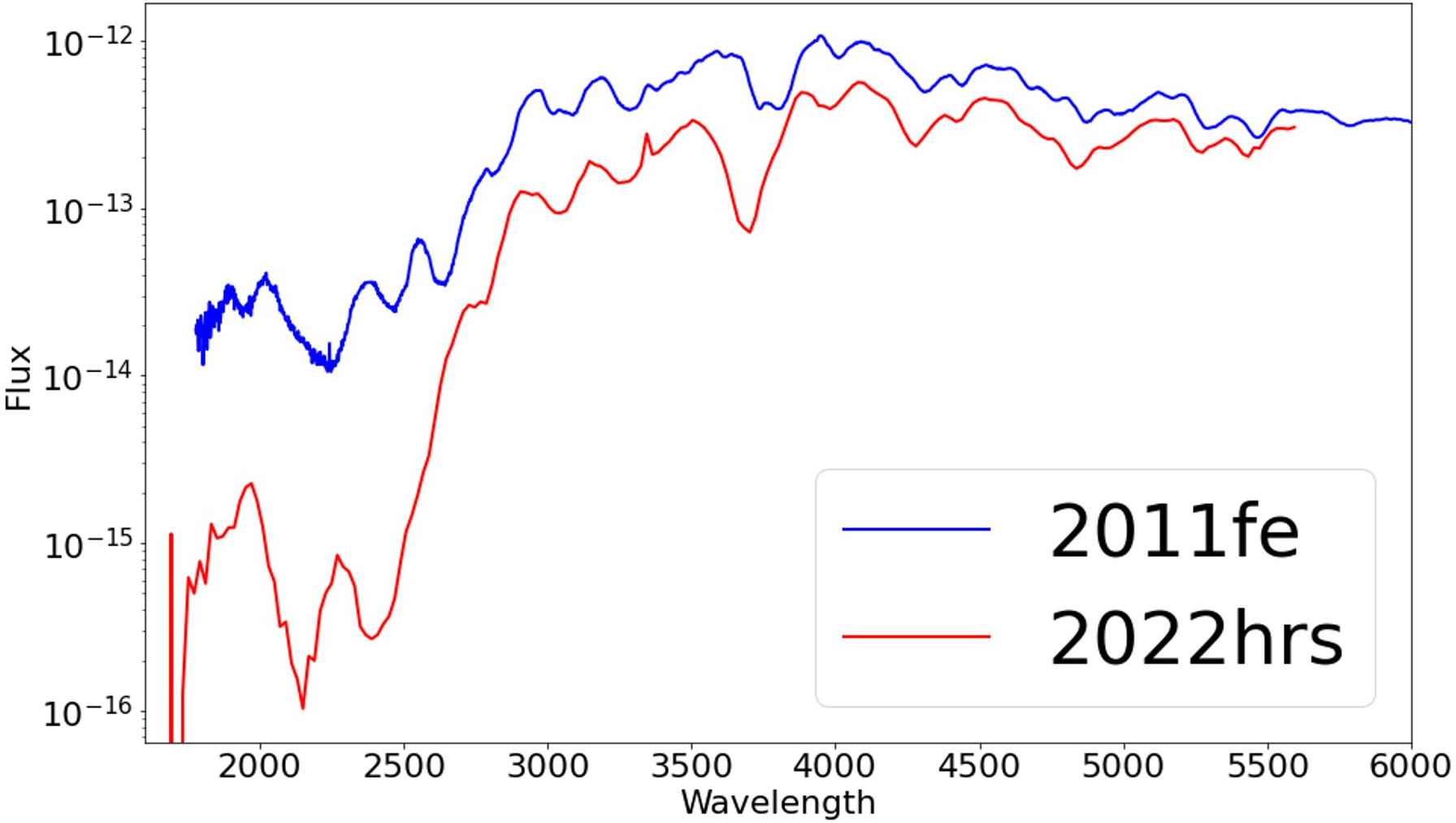


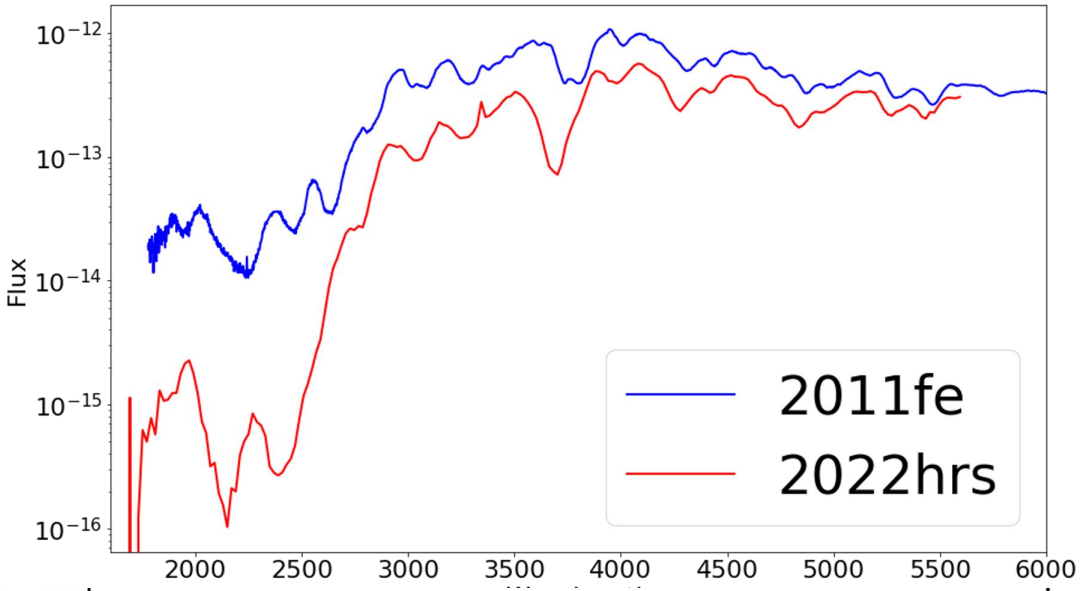
Comparisons with Walker et al. (2012) models point to metallicity as source of near-UV differences

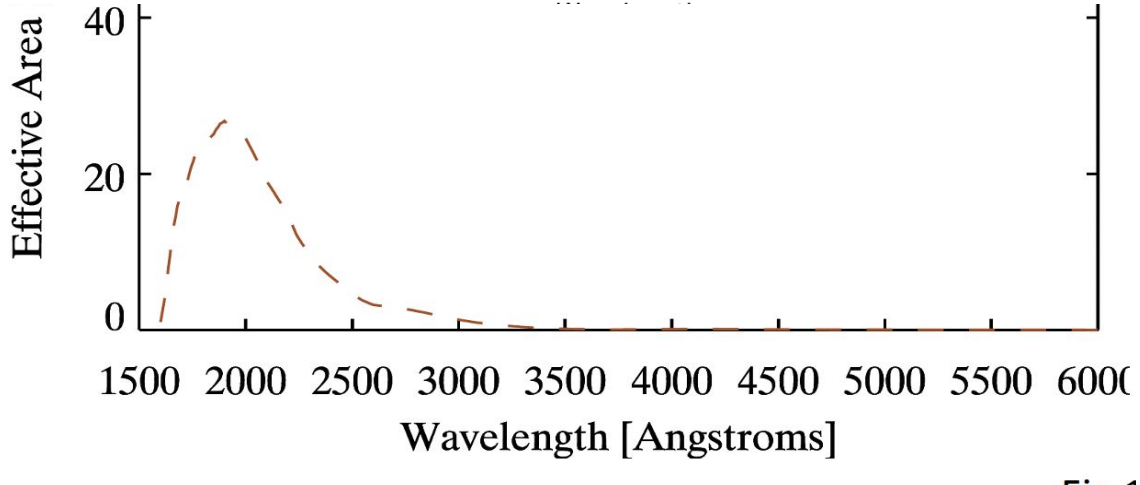




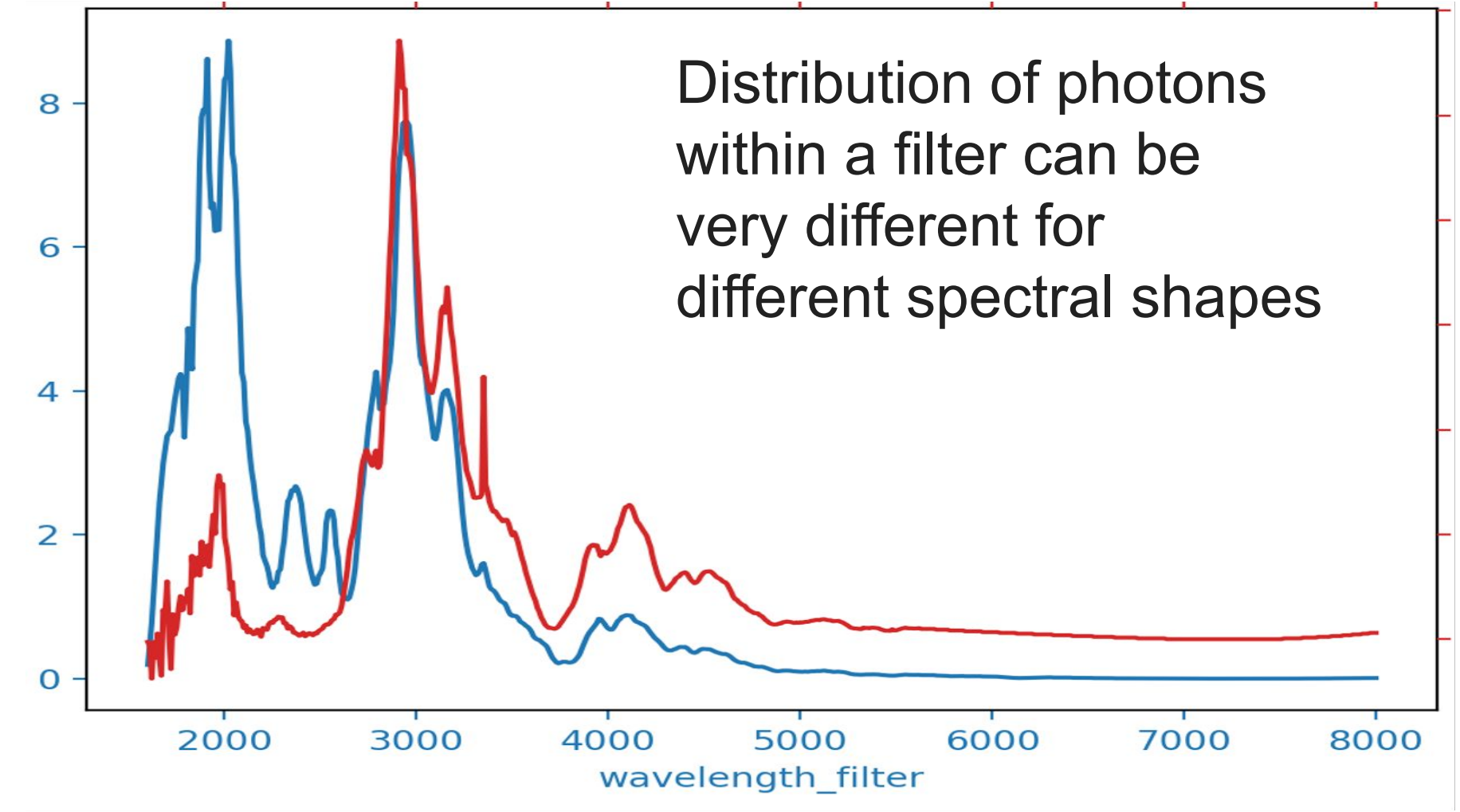
But SNe in the early universe will have systematically lower metallicities!


10^{-12}
10^{-13}
10^{-14}
10^{-15}
10^{-16}
Flux
2000
2500
3000
3500
4000
4500
5000
5500
6000
Wavelength
2011fe
2022hrs

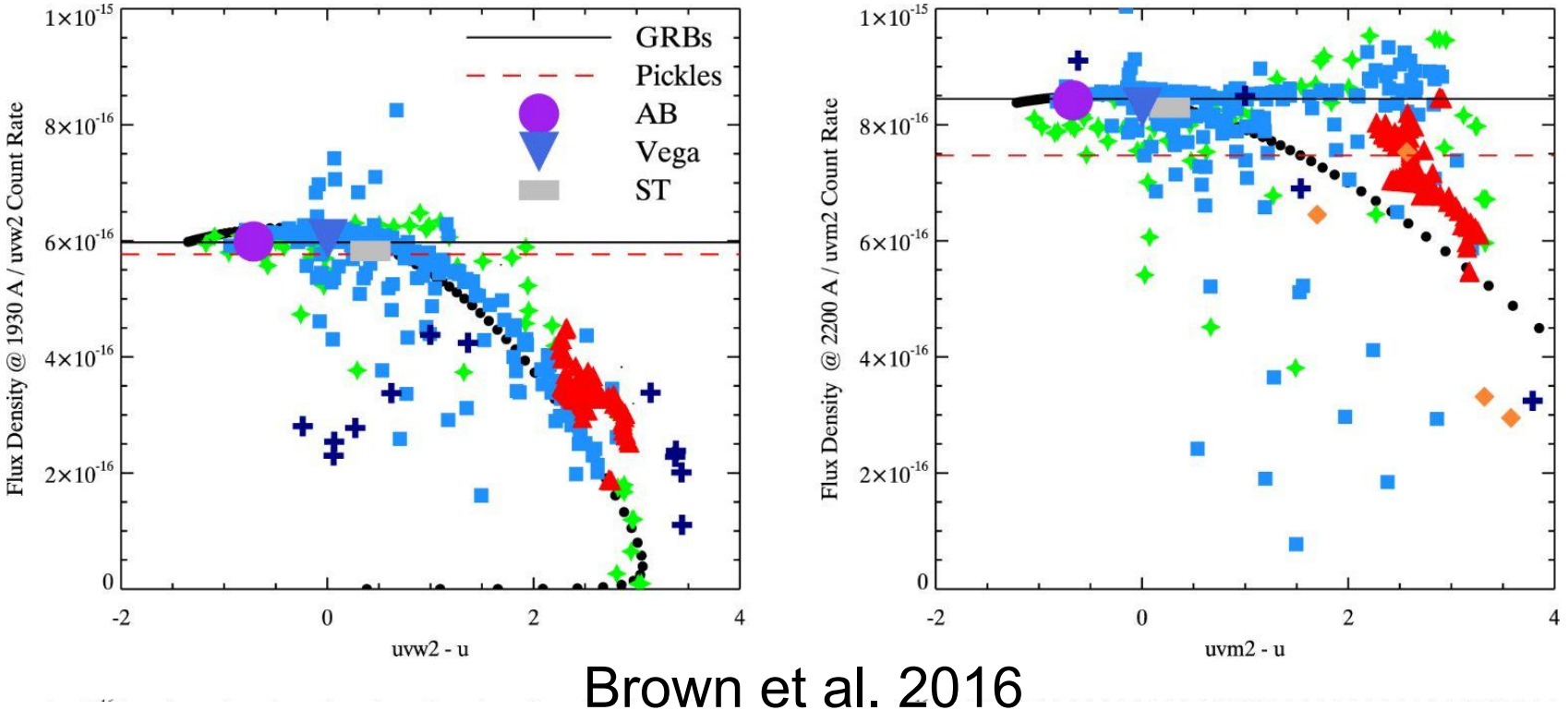




Broadband filters can cross over large spectral changes

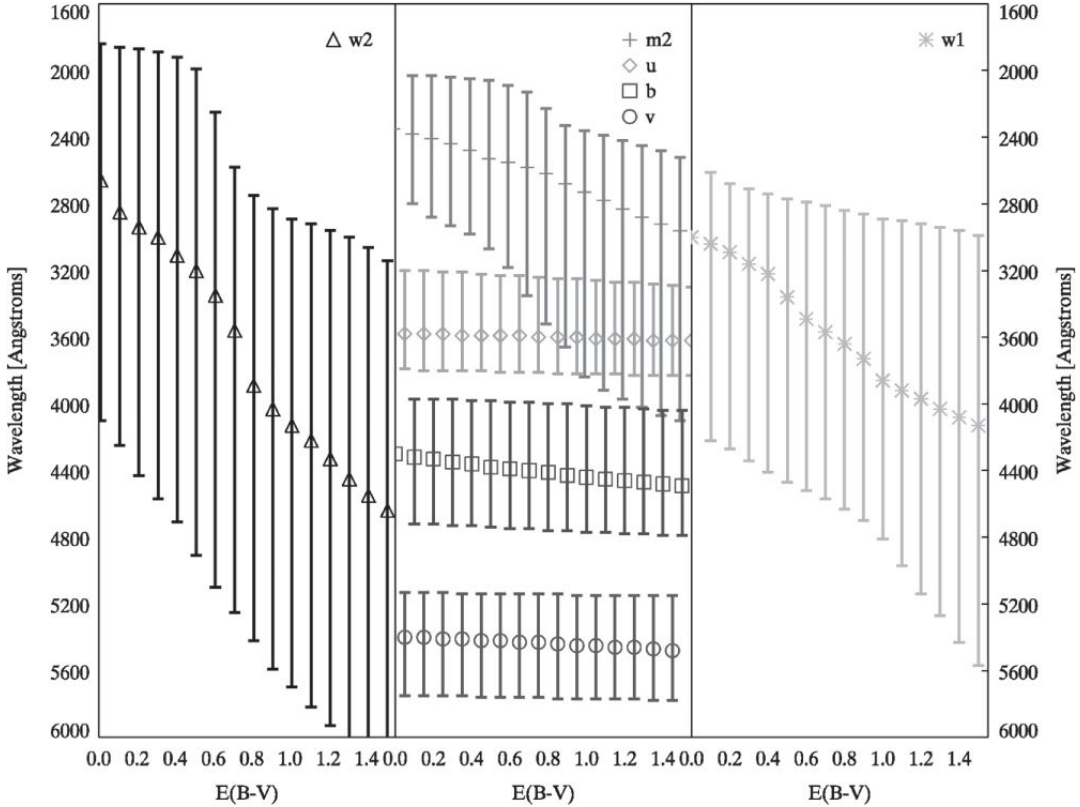

Distribution of photons within a filter can be very different for different spectral shapes
8
6
4
2
0
2000
3000
4000
5000
6000
7000
8000
wavelength_filter

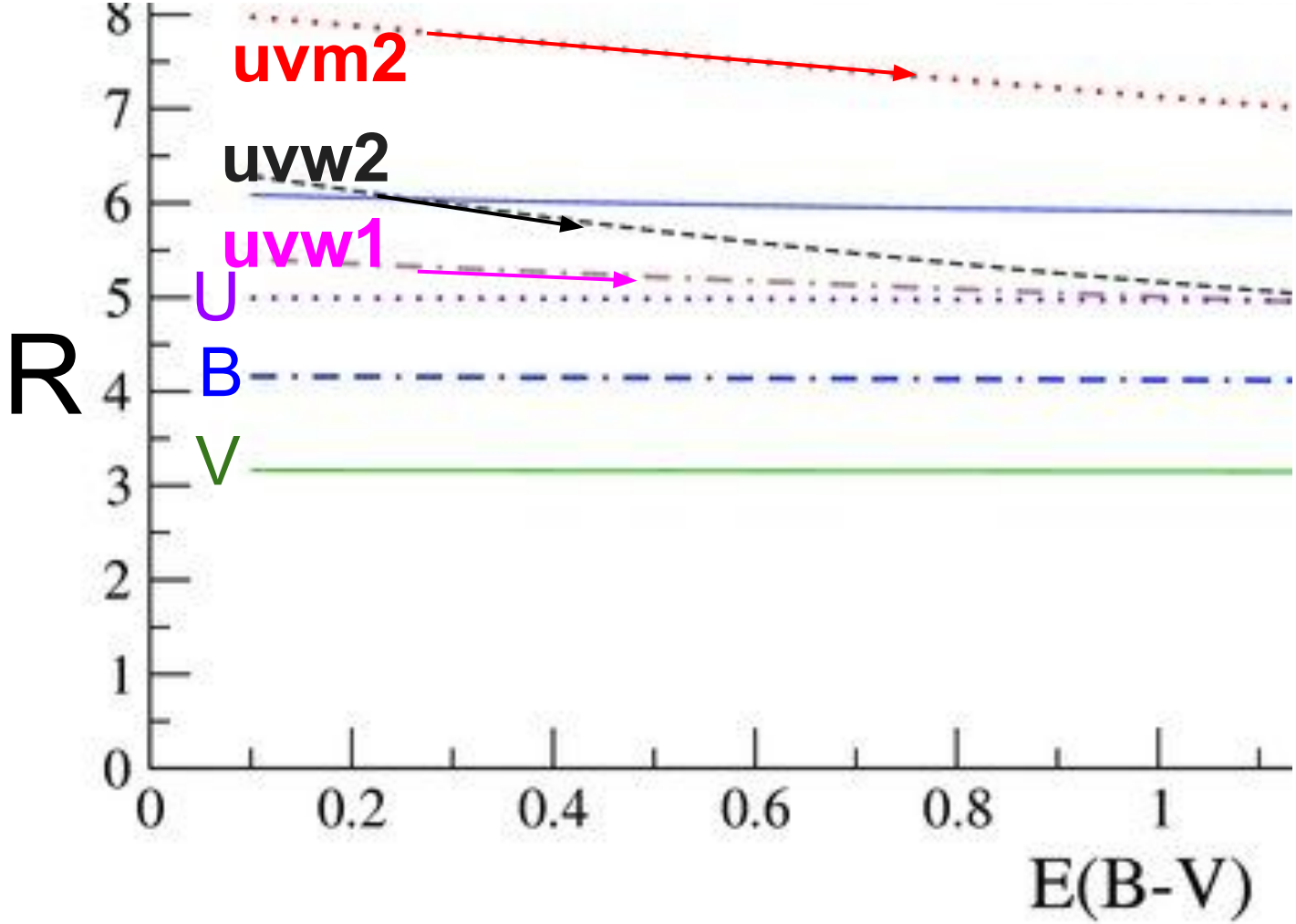
Flux conversion factors depend on spectral shape



Brown et al. 2016

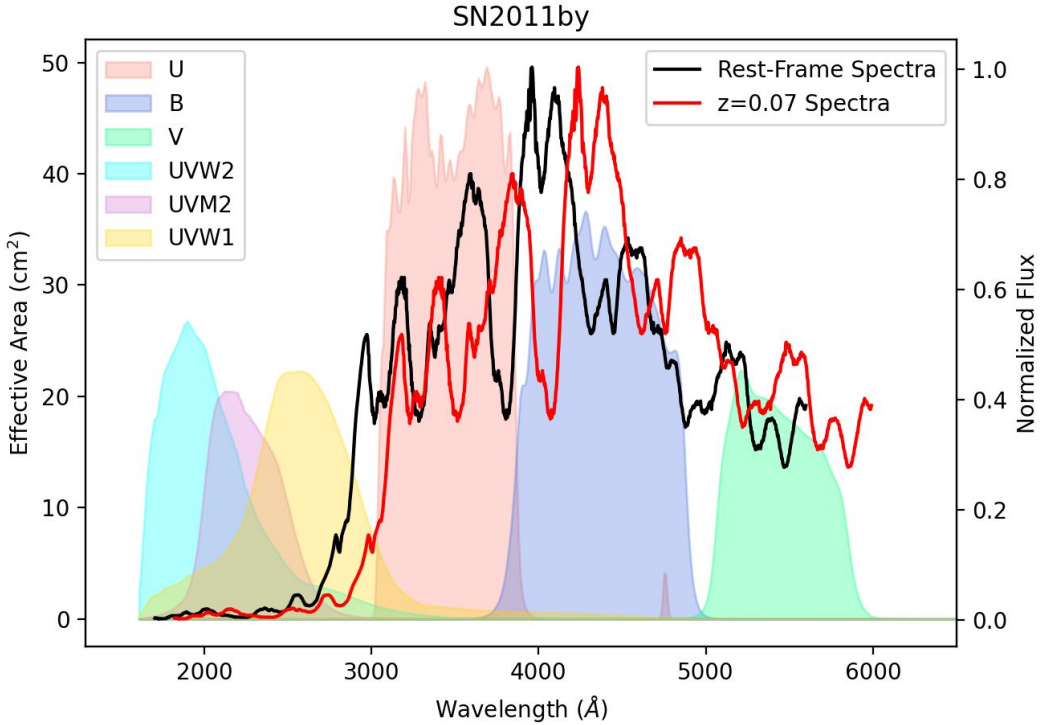
Effective wavelength of UV filters shifts (Brown et al. 2015)



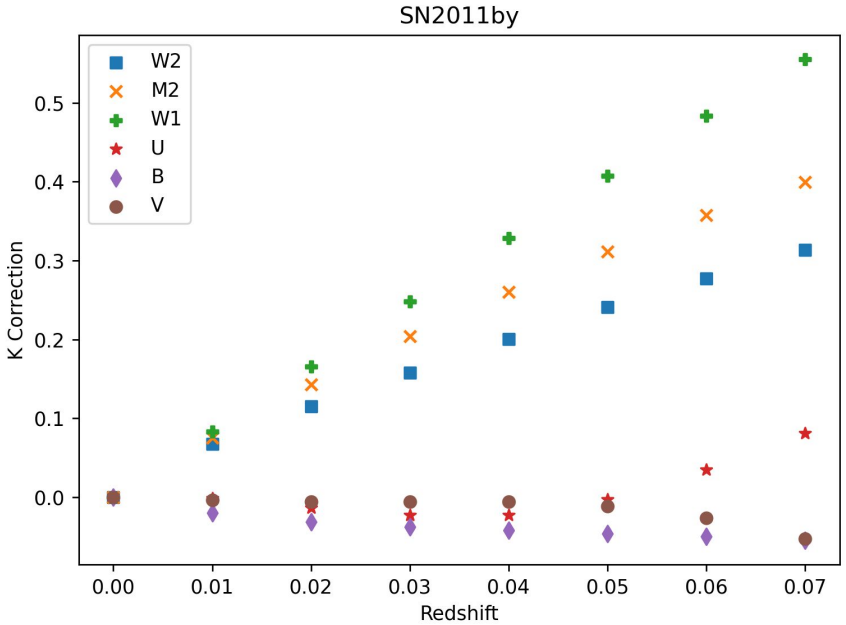


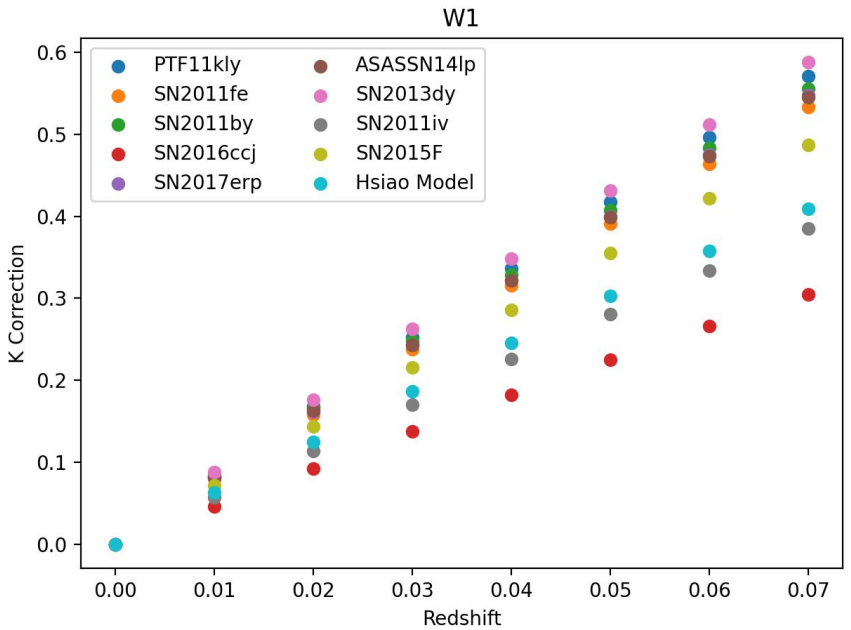
Broad-band Extinction Coefficients in the UV change with reddening or color

Studying distant SNe in the rest frame UV likely requires photometry, but proper interpretation of photometry
requires spectra to correct for redshifting and other effects.

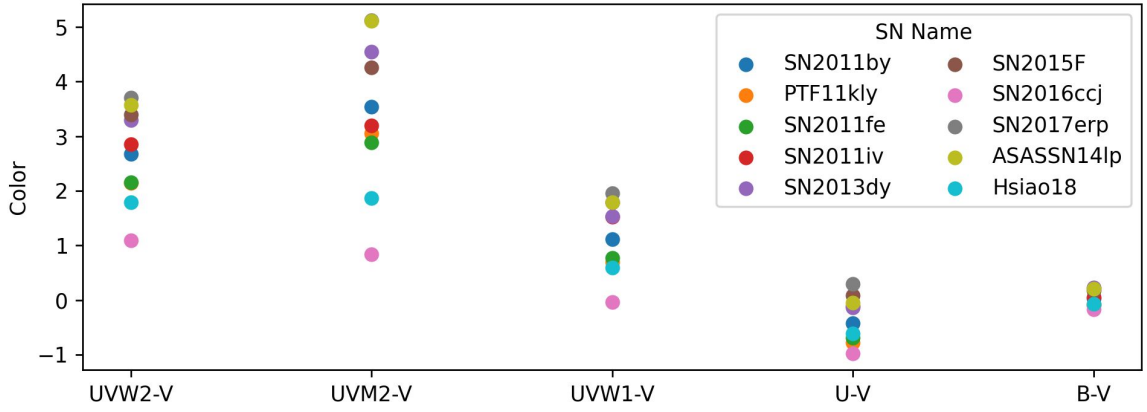


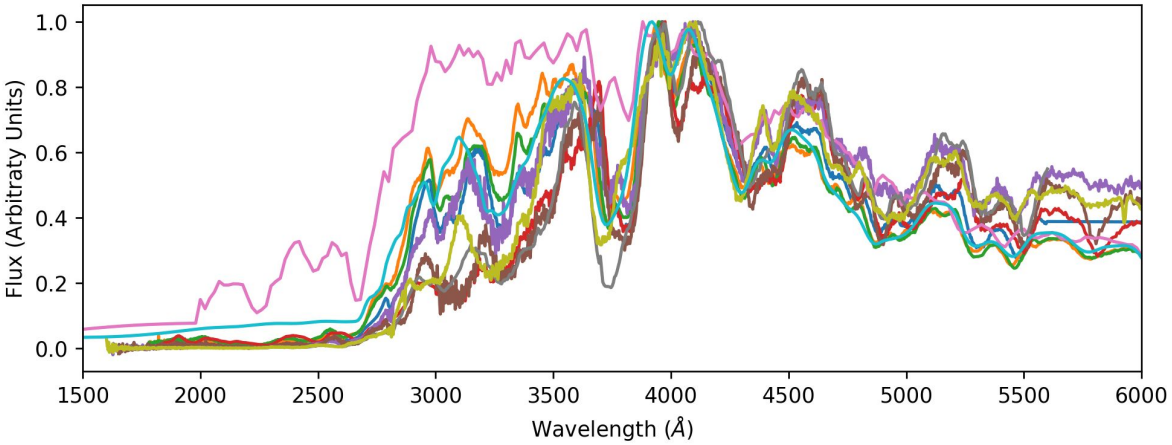
K Corrections are larger and more varied In the ultraviolet filters

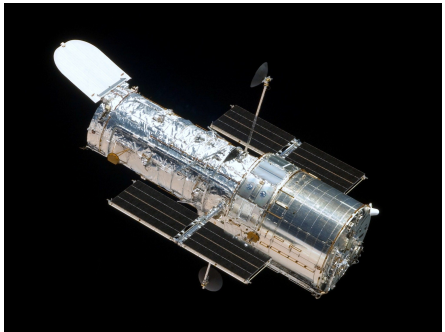


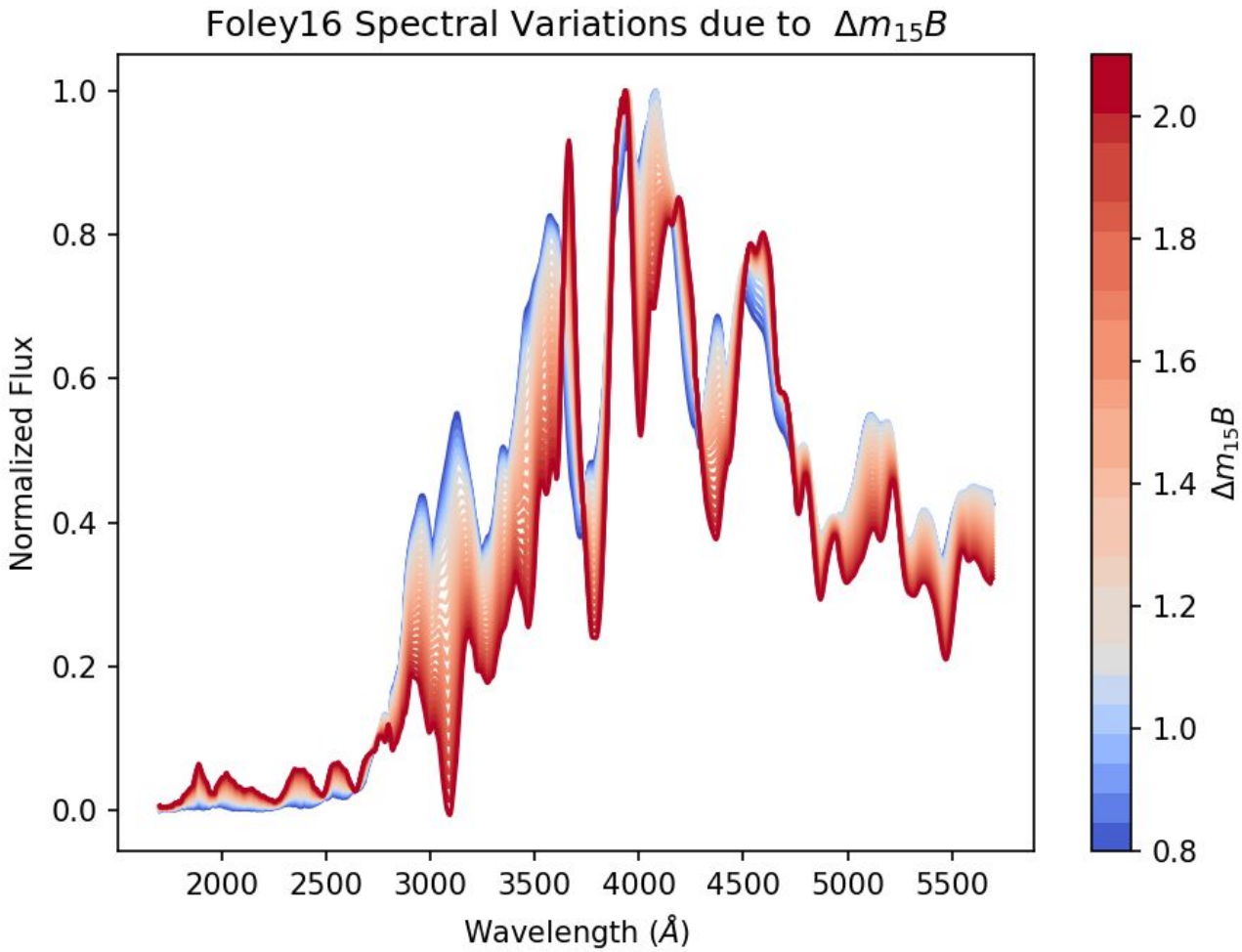


A Template Spectral Library is used to find and/or create spectra which match the observed photometry (Devarakonda 2023)

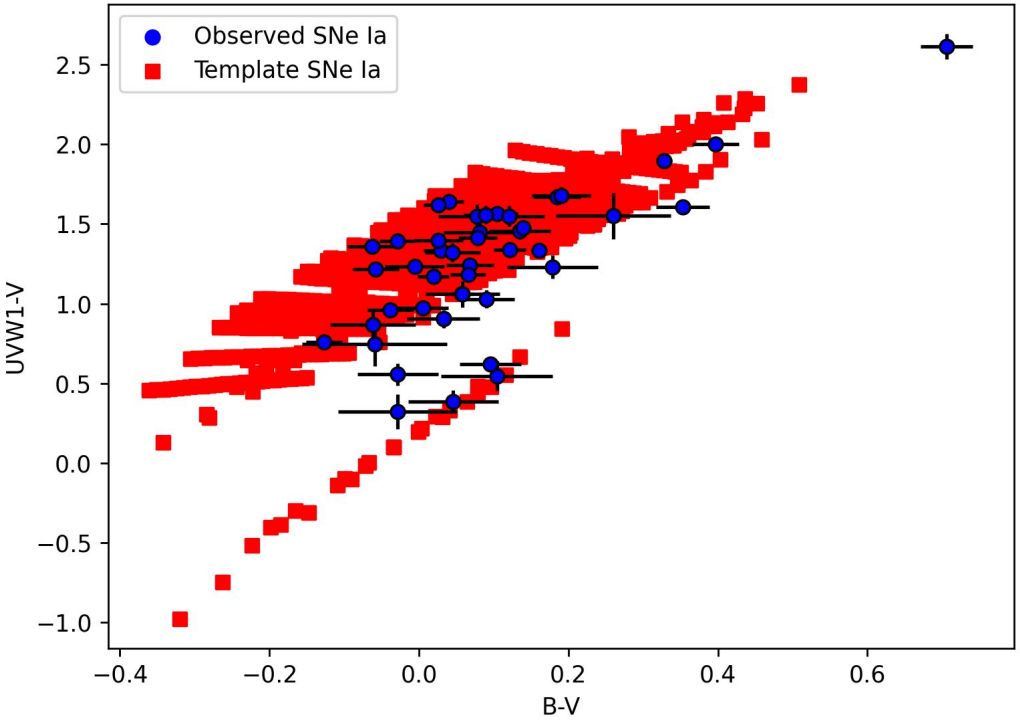




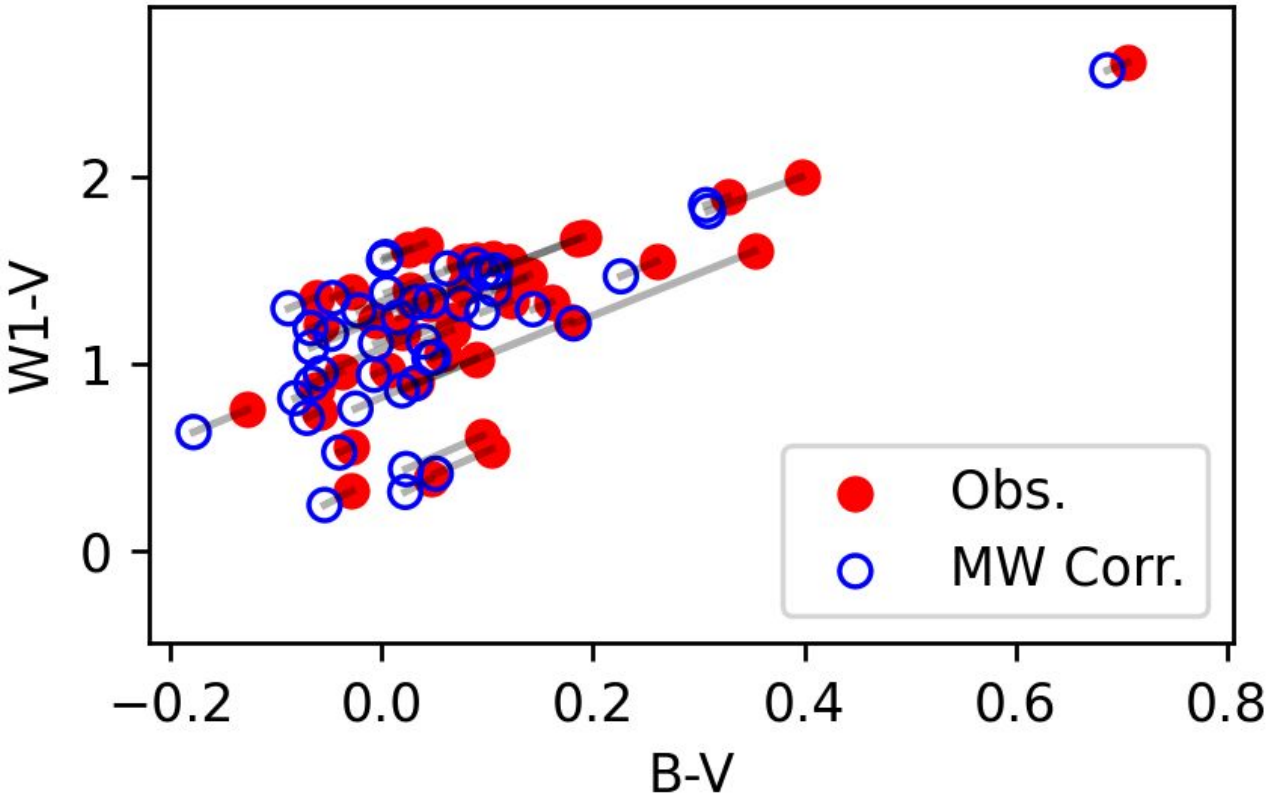



Foley16 Spectral Variations due to $\Delta m_{15}B$
Normalized Flux
0.0
0.2
0.4
0.6
0.8
1.0
2000
2500
3000
3500
4000
4500
5000
5500
Wavelength (Å)
$\Delta m_{15}B$
0.8
1.0
1.2
1.4
1.6
1.8
2.0

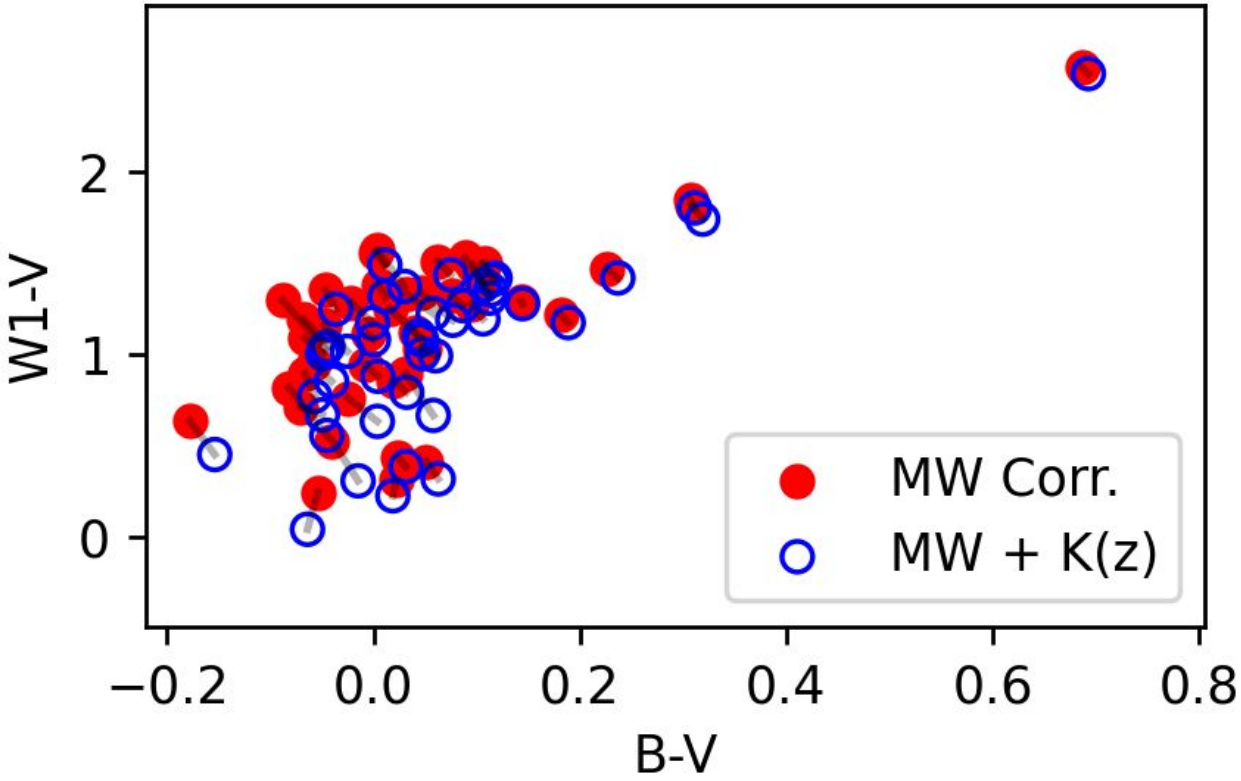
Template models are reddened by different amounts to cover the color-color space of the photometry. The best matches to the observed photometry are used.



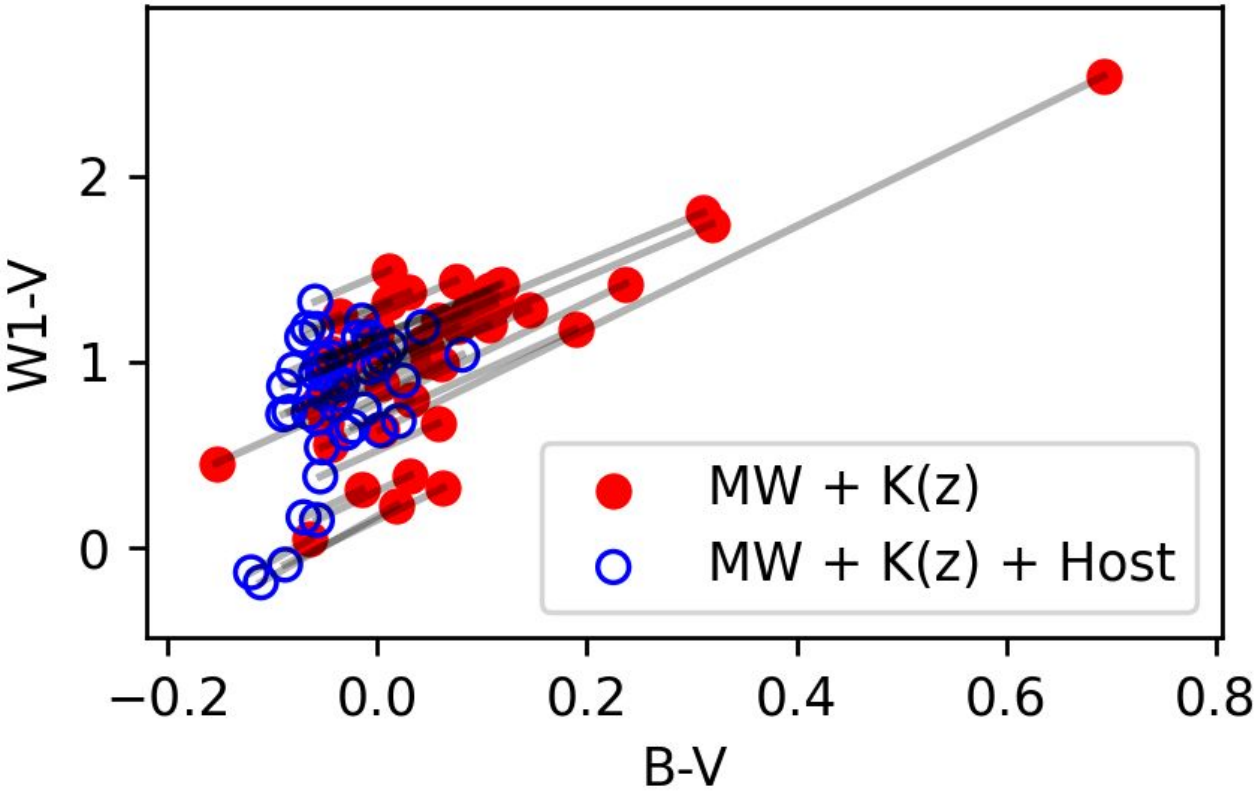
These observer-frame models can be used to compute the appropriate correction for MW



Deredshifting these models can be used to compute the appropriate correction for k corrections

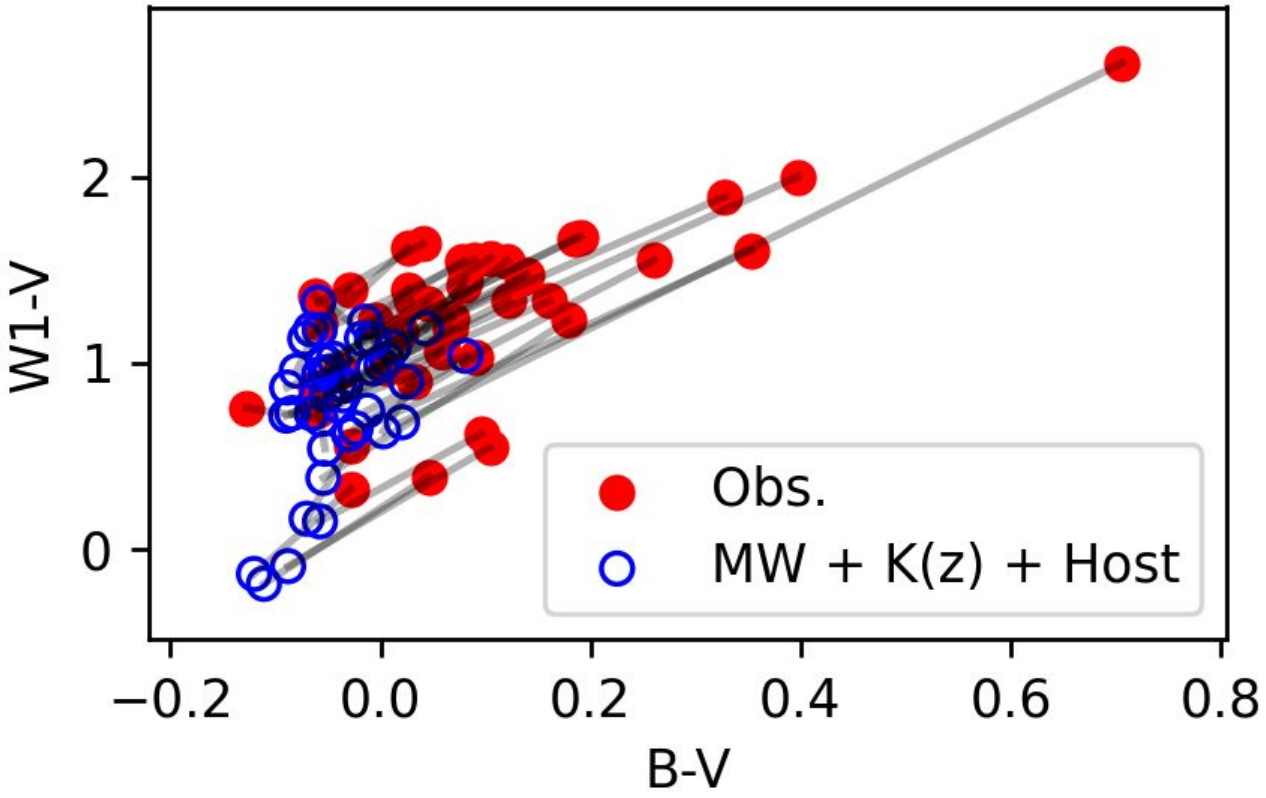


The dredshifted models can be used to compute the appropriate correction for host reddening



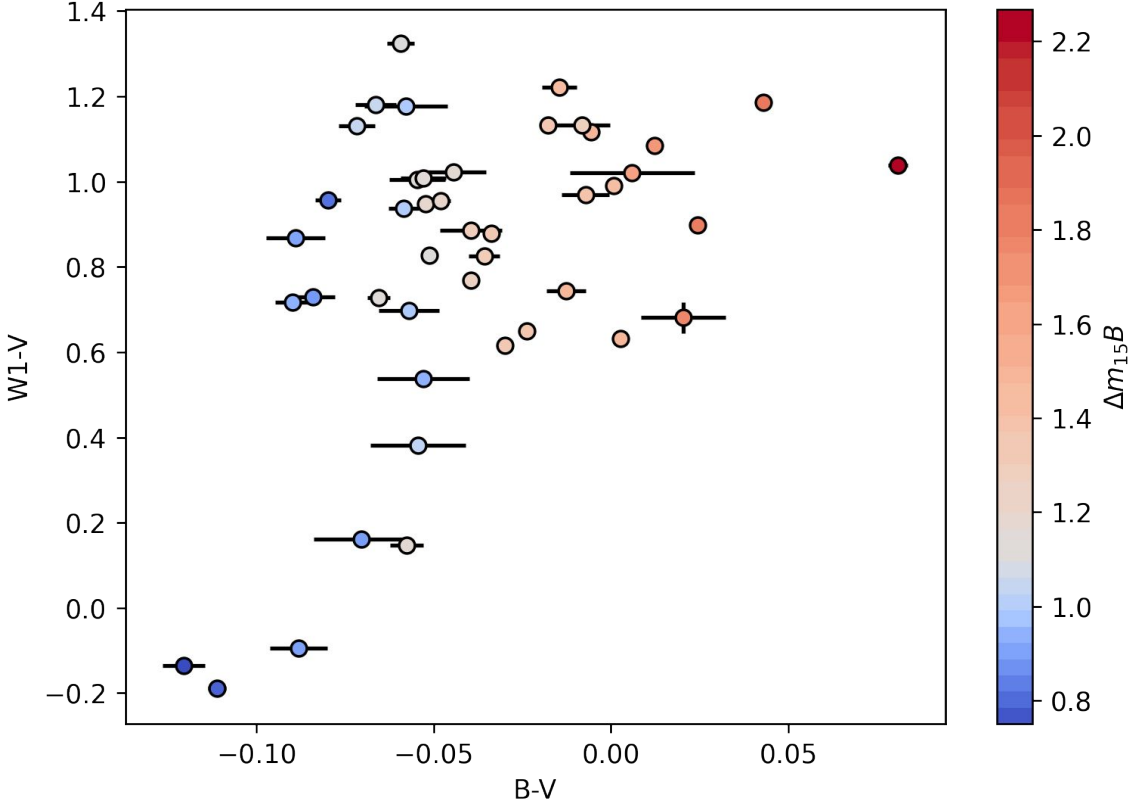
Here we have assumed intrinsic B-V colors based on light curve shape from Phillips et al. (1999)

Combined Corrections



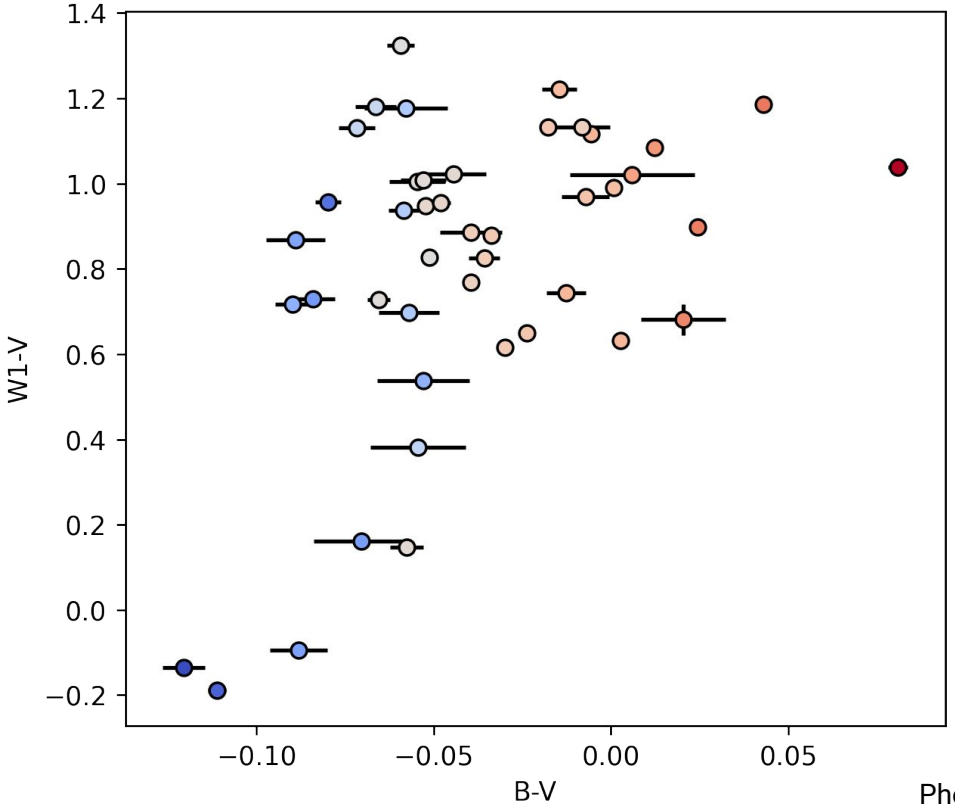
Devarakonda (2023)

Final “intrinsic” colors



Properly corrected colors can be better correlated with SN and host properties to explain the UV diversity independent from spectroscopy

Final “intrinsic” colors



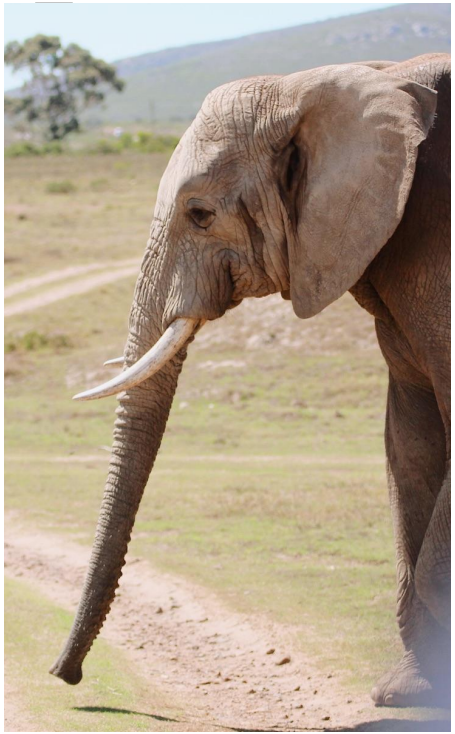
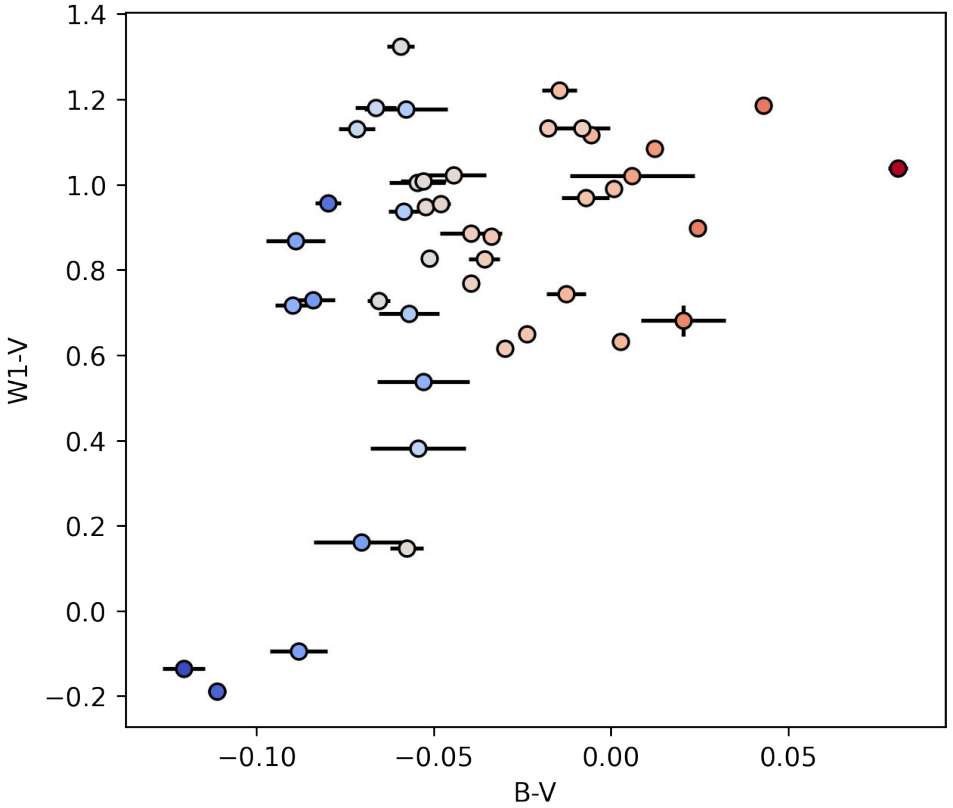
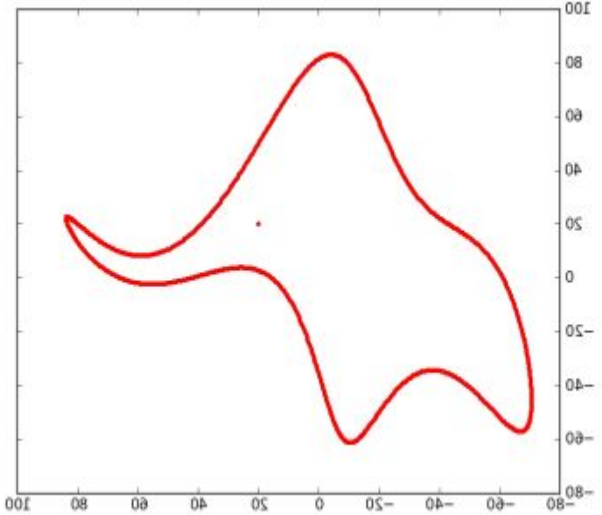
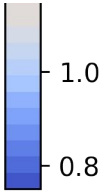


Photo by Gina Alexandra Jacobs:
https://www.pexels.com/photo/african-elephant-in-savannah-16049579/

Final “intrinsic” colors

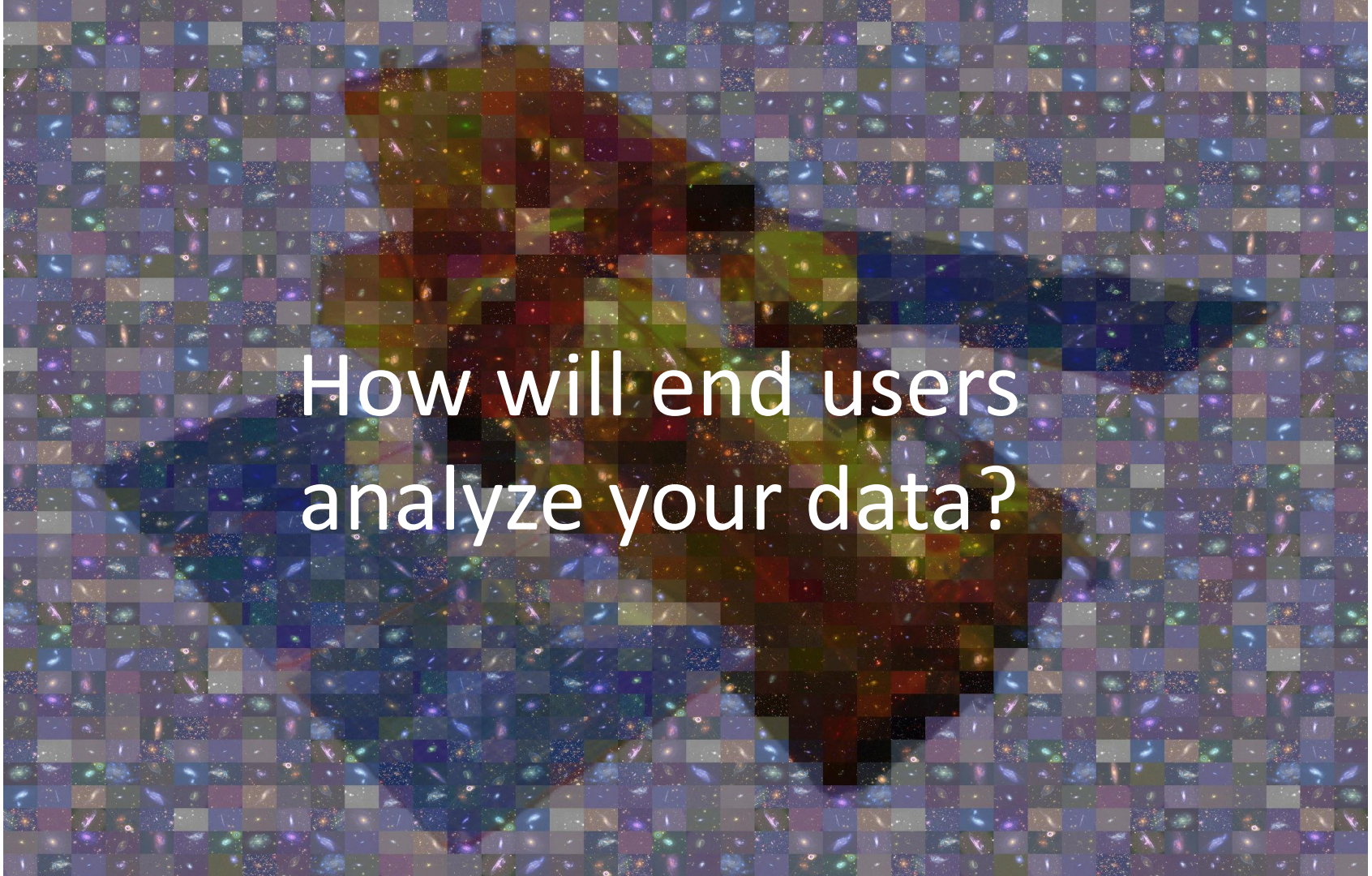






Drawing an elephant with four complex parameters

Mayer et al. 2010
https://www.johndcook.com/blog/2011/06/21/how-to-fit-an-elephant/


How will end users
analyze your data?


How should end users
analyze your data?


How could end users misuse your data?